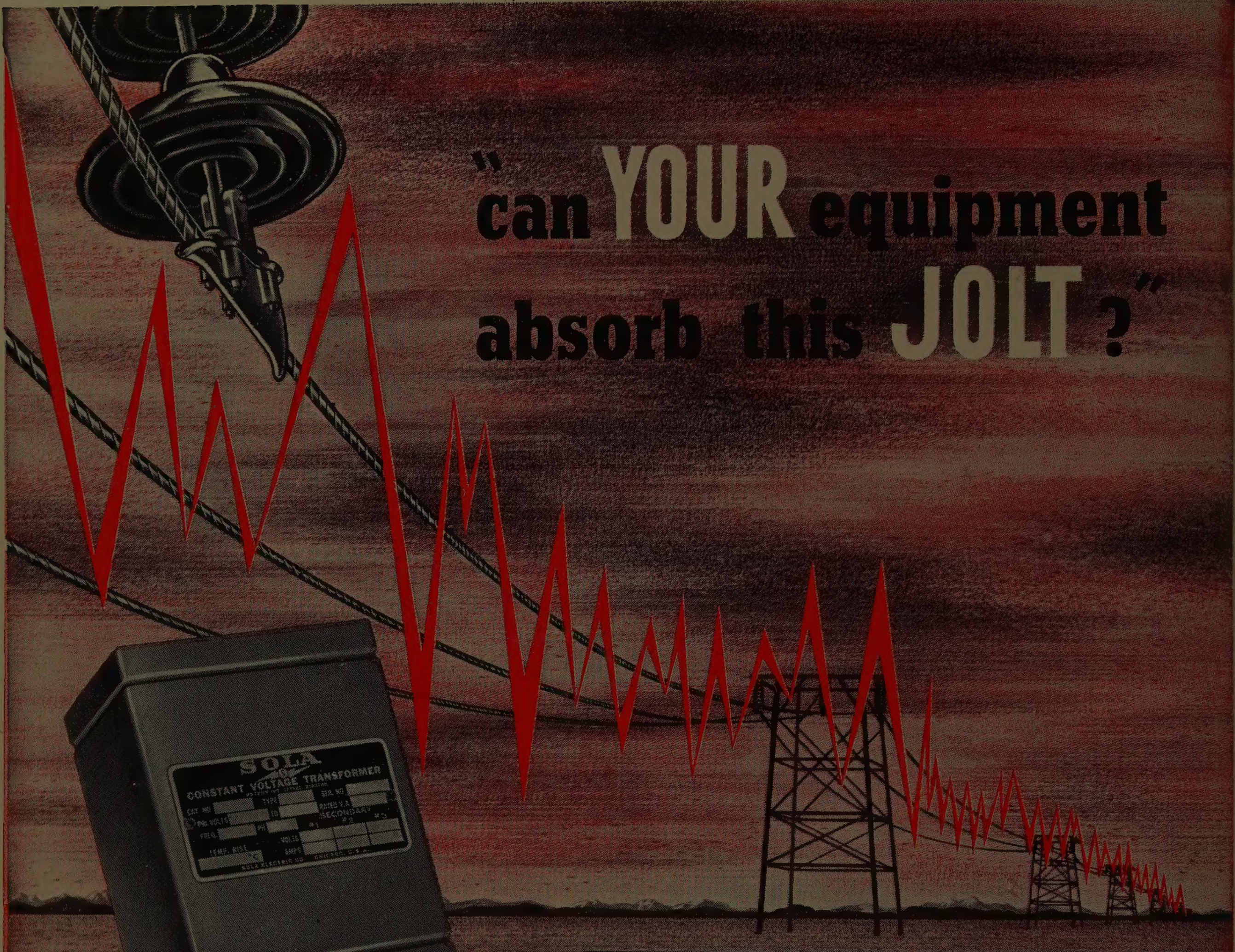
ELECTRICAL ENGINEERING

OCTOBER 1947

AIEE MIDWEST GENERAL MEETING, CHICAGO, ILL., NOVEMBER 3–7, 1947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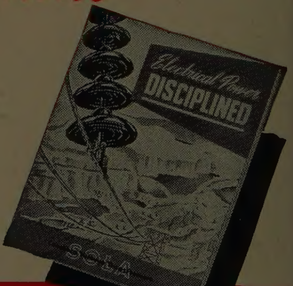

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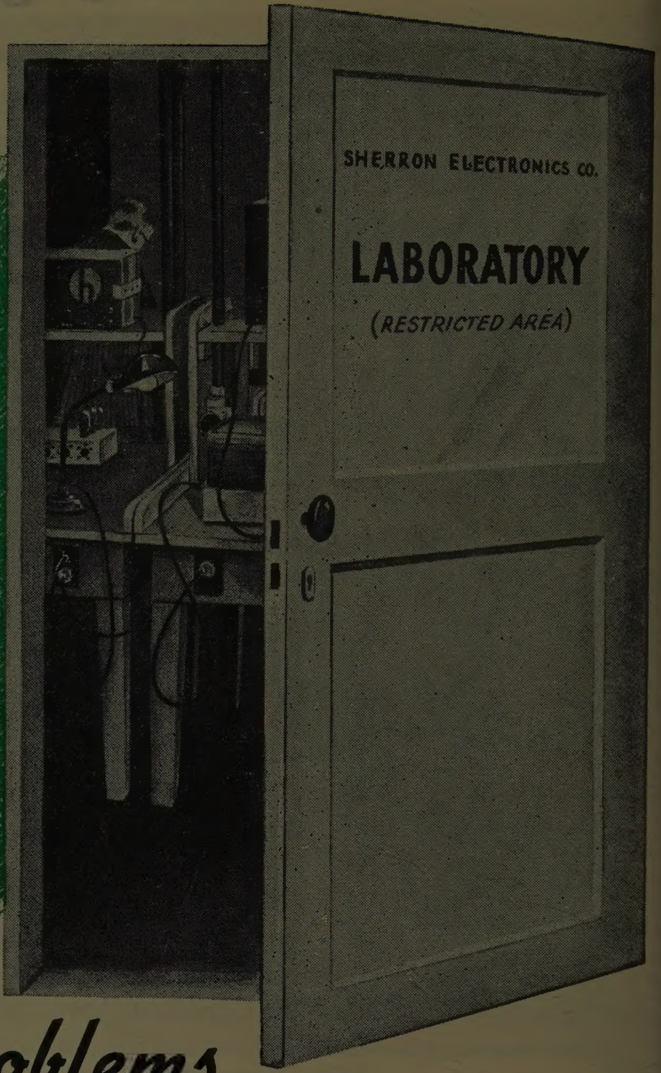

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German Electrical Utilities in Wartime

JOHN G. NOEST
MEMBER AIEE

At the beginning of World War II, the overall operation of Germany's electrical utilities was taken over by government authority for the purpose of achieving maximum utilization of existing capacity through nation-wide interconnected operation. However, in spite of all efforts to the contrary, capacity slowly deteriorated, until the severe damage inflicted by Allied forces during the last month of the war led to the industry's almost complete collapse.

SINCE the late 1920's the German electrical utility industry has been undergoing a steady process of unification by which local companies became interconnected with each other and with larger interstate companies. While the former were privately or municipally owned, the larger interstate companies generally were co-owned by the central Government. Also significant was the steady expansion of interconnection with industrial plants, for which the source of pre-Nazi pressure toward unification was the promise of more economical operation.

ORGANIZATION

In 1935, through the Energy Economy Law, control of the German electrical utility industry (as well as other industries producing energy as major product) was vested in the Minister of Economics, who, through the Office for Energy, directed operating methods establishing interconnections and regulating the location and magnitude of new plant development.

When Germany invaded Poland in 1939, complete control of German electrical utilities passed into the hands of the National Load Dispatcher by executive order. The National Load Dispatcher immediately subdivided greater Germany (including Austria and the Sudeten area) into 12 (later 13) energy districts, each under the immediate supervision of a District Load Dispatcher who, in turn, was in immediate control of all Local Load Dispatchers within his district. The chain of authority was direct.

CAPACITY AND GENERATION

Assessment of the capacity and generation of the German electrical utility industry is complicated by the various territorial changes and by the continual transfer of noninterconnected private plants to interconnected plants. Tables I, III, and IV give a summary of data, which became available shortly after the war. Table II gives a comparison with data for the United States.

In the years from 1937 to 1942 the capacity increase per year averaged 543 megawatts per year. The value of 543 megawatts per year included gains due to acquisition of Austria and the Sudeten as well as new construction. New plant construction alone is estimated at 400 megawatts per year which gave a capacity increase of approximately 4.38 per cent per year. The capacity increase from 1942 to 1943 was 800 megawatts or 6.75 per cent per year. This was the result of the accelerated completion of large water power projects in southern Germany and western Austria, as well as the result of accelerated construction of new plants, started with the beginning of the war, and of existing plant expansion. To the middle of 1943, utility plant expansion enjoyed high priority. A large percentage of new development occurred in a new central German industrial area, development of which was undertaken because of the vulnerability to aerial attack of the principal industrial concentrations in the Northern Rhine–Ruhr area.

In 1941, it was realized that the public utility industry was becoming overloaded, and steps were taken toward the prompt construction of additional capacity in central Germany. Plans were made for the construction of ten identical plants, with equipment to be standardized, each of 300-megawatt capacity. Despite the fact that these plans had high priority initially, not a single plant of the ten actually was completed, or even was in partial operation, at the end of the war. The original high priority was lowered as time went on and, eventually, already installed equipment was removed for replacement use in damaged older plants.

The capacity expansion between 1943 and 1944 was 650 megawatts, most of which also came from projects begun before 1942.

The growth of the maximum demand on plants reached a peak at the end of 1943 and then dropped off, principally as a result of intensified destruction of consumer plant facilities. A measurable part, however, was due to the efforts of the National Load Dispatcher toward improvement of the load factor. The appointment of energy conservation engineers for each larger industrial producer group resulted in many factories, still on a 6-day work week, shifting the holiday to week

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Essential substance of paper **47-135**, "The German Electrical Utility Industry During World War II," presented at the AIEE summer general meeting, Montreal, Quebec, Canada, June 9–13, 1947, and scheduled for publication in AIEE *TRANSACTIONS*, volume 66, 1947.

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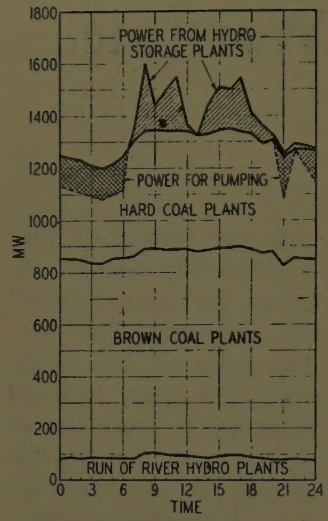

Figure 1. Typical daily load chart of the RWE system

days. Other factories, not working on a 24-hour basis, transferred their shifts into the off-peak periods.

Beginning with 1942, the peak load was smaller than the maximum demand, because of the general application of load curtailment for consumers. The curtailment program was set up originally to permit prompt load reduction in case of damage to utility plants by enemy action. Designed to operate in ten steps, the tenth step was calculated for a load reduction of 30 per cent. Curtailment was applied in two ways: continuous curtailment, based on kilowatt-hour consumption, and spot curtailment on maximum demand. Continuous curtailment was administered by the Ministry of Economy, so that industries were allotted energy just as they were allotted raw materials. Curtailment of maximum demand was administered by the National Load Dispatcher through the district and local dispatchers. On the maximum demand curtailment list were principally large consumers, who could be ordered, on instant notice, to drop load according to prearranged steps. An order to reduce load could be put into effect in two hours without resulting in spoilage of products.

Another most significant effect of the war is visible in the values given for capacity loss due to unscheduled outages. All plant operators interviewed attributed this to the policy of deferring maintenance work, a policy adopted on the premise of a short war. As the war progressed, the time required for major repair work increased in direct proportion to the overloading of the railroads and to the lack of experienced personnel in the factories of equipment manufacturers. At the end of 1942, nonscheduled outages amounted to 5.5 per cent of installed capacity. For 1943 the percentage had increased to 6.76 per cent and to 9.1 per cent for 1944. Only for the latter half of 1944 was this situation compounded by increasing difficulties in railroad transportation and by air damage to equipment manufacturers' plants. Authorities responsible for man power allocation also were blamed for permitting indiscriminate absorption of key personnel into the armed forces.

Table II, giving comparative data for the electrical utility industries of the United States and Germany, is an index to industrial potential—if consumption of electric energy is a measure—which should have given Germany cause for hesitation. The industrial potential of United States industry is shown to be approximately 5 times that of German industry (ratio 2 times ratio 3). Although these ratios are based on public utility capacity and generation statistics only, and are, therefore, not all-inclusive, as they omit private plant values, they are of value for comparative purposes.

GENERATING FACILITIES

Tables III and IV show that approximately 70 per cent of the total plant capacity existed in thermal plants, of which approximately 30 per cent depended on brown coal. While the hard coal burning plants were little different from those in the United States, except for consistently smaller turbogenerator sets and certain boiler developments, the brown coal burning plants have no American counterpart. Initially, these plants were only by-product plants in an industrial complex with such primary purposes as the production of illuminating gas, brown coal, briquettes for public sale, or chemical products in various combinations.[5] Typical brown coal plants invariably were found assembled about an open pit brown coal mine with seams varying in thickness from 3 to 50 feet, under an overburden from a few feet to 30 feet in depth. The brown coal, having a heat content varying between 3,000 and 5,000 British thermal units per pound and from 50 to 60 per cent moisture, was stripped by mechanical shovels, scrapers, or conveyers, and loaded, either on standard railway cars, on transport conveyers, or on rope trolley systems for transportation to the near-by plants. In view of its low heat content, transportation of the coal any great distance is economically impossible. The cost of this coal, delivered to the generating plant, was given at 2.00 reichsmark per metric ton, while the cost of bituminous coal of 14,400 British thermal units per pound was 14 reichsmark per metric ton in the same area (Ruhr).

A large portion of the brown coal was delivered to plants where it was dried and compressed into briquettes, having a heat content of approximately 9,000 to 10,000 British thermal units per pound, with a moisture content of from 10 to 15 per cent. The briquettes were used in the manufacture of gas and coke and were sold to the public. The heat for drying the coal was obtained from back pressure turbines in the electric power plant. To complete the utilization of the products of the coal pit, the electric plant's boilers generally were designed to burn brown coal as mined, with auxiliary burners for gas or for powdered coke. These brown coal plants invariably were designed and operated as base load

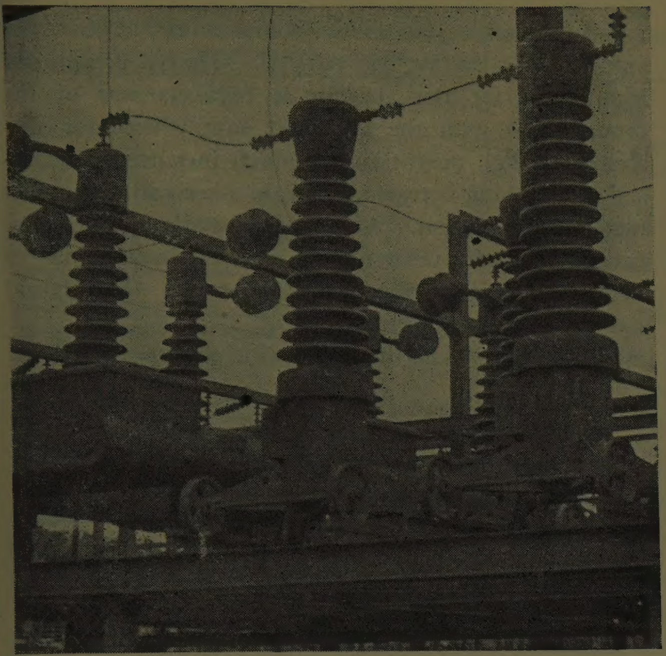

Figure 2. AEG Freistrahl circuit breaker (extreme left) 110 kv, 1,500 megavolt-amperes, with current and potential transformers

plants with load factors in the neighborhood of 90 per cent. Most of these plants operated with steam pressures up to 400 pounds per square inch, although a few had topping turbines and high pressure boilers, operating with pressures up to 1,600 pounds per square inch and steam temperatures near 1,000 degrees Fahrenheit. Topping turbine installations were found more frequently in hard coal burning plants. Turbogenerator sizes were usually below 50,000 kw, although one plant had two 100,000-kw units. Lyungstrom turbogenerator sets always were praised by plant operators for high efficiencies and low maintenance.

As practically all brown coal burning plants were located at the site of the pits, condenser circulating water had to be obtained by recooling in large cooling towers, most of which were built of wood on steel frames, although the newer ones had concrete frames. Typical dimensions and data are: Base diameter 151 feet, height 188 feet, top diameter 80 feet, capacity 35,000 gallons per minute, 10 degrees centigrade cooling effect.

A noteworthy development was found in hydroelectric plants. The utility industry, aided by government subsidies, had invested heavily in hydro storage plants, both of natural storage and of pumped-storage type. Although exact statistics were not found, it is estimated that about one half of the hydroelectric plant capacity existed in such storage plants of which one half again was either pure pumped storage or natural and pumped-storage combinations. Description of a typical pumped-storage plant can be given best in terms of the Koepchenwerk located on the Ruhr River, some 15 miles east of Essen.

This plant contained three complete and one incomplete hydro turbine generator pump units. Each unit consisted of a horizontal shaft Francis turbine, a 32,000-kw 0.8-power-factor synchronous generator, and a 27,000-kw 2-stage centrifugal pump. Connecting the pumps to the generator's shaft was a hydraulic mechanical coupling with a dual function: It accelerated the pump to approximately 95 per cent of synchronous speed, and then, for final acceleration to synchronous speed, used its plate-type friction element, which, at synchronous speed, transmitted the required torque without slip. When the unit was used to pump, the turbine runner rotated with the generator and pump, while the turbine casing was unwatered. All controls required for a complete change from generation to pumping, and vice versa, were operated by an automatic sequence device, the operation of which was initiated by push button. The hydro turbine and pump operated with a head of from 517.5 feet to 582.5 feet. On top of a hill, an 18.5-acre reservoir with a change of elevation of 65 feet stored 55 million cubic feet of water. This reservoir was connected to the generating station by means of penstocks 1,050 feet in length. A lower reservoir, known as the Hengsteysee, created by a small concrete dam across the Ruhr, also furnished water to the Krupp factories in Essen.

Three pumps operating at full capacity for ten hours were capable of filling the reservoir. This operation required 810,000 kilowatt-hours. The over-all efficiency being 65 per cent, a useful storage of energy equal to 525,000 kilowatt-hours was accomplished. This energy could be released by full capacity operation of all generators, giving 128,000 kw for approximately 4 hours. In addition to providing peak capacity, this plant and others of its kind were used as synchronous condenser capacity by operating the generator uncoupled from the pump with the turbine unwatered.

Construction of this plant, which was started in 1929 and reached its present stage in 1932, was accomplished at a cost of 43.7 million reichsmarks, giving a construction cost of 341 reichsmarks per kilowatt, which compares with 500 to 520 reichsmarks per kilowatt for contemporary steam plants.

The RWE (Rheinische-Westphälische-Electrizitatwerke A.G.) System, which supplied 23 per cent of German electric energy with a nominal capacity of 1,850,000 kw, owned approximately 300,000 kw of pumped and natural storage plant capacity, that is, 16.2 per cent of its total capacity. By means of these plants, this system was able to operate its brown coal plants with a load factor of near 90 per cent. Figure 1 shows a typical load curve.

PLANT EQUIPMENT

German generating station equipment was much the same as in the United States. Generator sets were generally smaller, with ratings from 25–50-megawatt ca-

Table I. Statistical Review of the German Electrical Public Utility Industry

	1937[1]	1942[2]	1943[2]	1944[2]	1945*[2]
Nominal capacity of generating facilities, mw	9,130	11,850	12,650	13,300	13,300
Capacity loss due to war actions, mw		0	370	2,060	3,110
Capacity loss due to unscheduled outages, mw		650	855	1,210	1,600
Available capacity (Name plate ratings), mw	9,133	11,200	11,425	10,030	8,590
Maximum demand (noncoincidental), mw	6,220	9,600	10,150	9,370	9,200
Peak curtailment, mw	0	375	610	1,780	3,100
Peak load (noncoincidental), mw	6,220	9,225	9,540	7,590	6,100
Peak curtailment in per cent of available capacity	0	3.45	5.35	17.75	36.1
Maximum demand in per cent of available capacity	68.2	85.1	88.8	93.4	107.2
Generation of electrical utility plants, million kwh	27,379	43,400	44,100	45,200	
Use factor of available capacity, per cent	34.2	44.1	54.4	51.4	
Load factor, per cent	50.2	53.5	52.9	68.0	

* For the month of January only.

Note: Maximum demand = peak load plus curtailment.

pacity most frequent. The most modern plants recently had installed high pressure topping units for which a standard capacity of 25,000 kw was set up by governmental decree. Such generators were 3,000 rpm, and generated voltages varied from 5,000 to 10,000 volts with the lower voltages in the majority. Generators generally were operated ungrounded. They usually were designed for 0.8 power factor, although 0.75-, 0.7-, and 0.625-power-factor generators were observed. Short-circuit ratios ranged between 0.5 and 0.7, with the older units tending toward higher ratios. Most units were provided with shaft exciters, while pilot exciters were practically absent. Considerable trouble was experienced with field winding distortion in the newer generators, particularly in the 3,000-rpm speeds. Automatic voltage regulation was general. No hydrogen-cooled generators were found. Station auxiliaries generally were driven electrically except for boiler feed pumps, where duplex drives with motors and steam turbines were common. Electric precipitators were used even in plants located far from municipalities.

Auxiliary supply was obtained generally from house service transformers; in the newer plants, tertiary windings on 110-kv transformers served the same purpose. A few installations of house generators, driven by the main turbine shaft, were observed.

CIRCUIT BREAKERS

A distinct difference from United States practice was observed in the almost total absence of oil circuit breakers. In newer stations, no switching was provided at generator voltage, except for auxiliary power; each generator was tied to the 110-kv bus by transformers with the switching on the high-voltage side. In older stations, practically all generator voltage switching was done by means of air blast circuit breakers, of which a great variety was seen. No phase isolation, either at generator voltage or at 110 kv, was noticed. The air compressor installation for the air circuit breakers was of the central type with the same air supply used for disconnect switch operation, in which instance pneumatical interlocking between circuit breaker and disconnect switches was general. A few older installations of liquid circuit breakers[5,6] were noted, and few installations of oil-poor circuit breakers were observed. The liquid was a mixture of water and glycol.

In the 110-kv class the three principal types were

1. Multibreak air blast.
2. Controlled expansion.
3. Free blast (*Freistrahl*) types (Figure 2).

In the 220-kv class the two prevalent types were 1 and 2. A 400-kv installation project contemplated the use of two circuit breakers, either type 1 or type 2 superimposed upon each other.

The *Freistrahl* is a most interesting type of circuit breaker design, which was built for 110-kv and 220-kv circuit voltages by the Allegemeine Electrizitats Gesellschaft (AEG) and Brown Boveri Company (BBC). It is an air blast circuit breaker without any sort of interrupting chute whatever. Two contact arms, mounted on insulators and capable of rotation either in a vertical or a horizontal plane, carry, surrounding a butt-type contact, an annular air blast nozzle. When this circuit

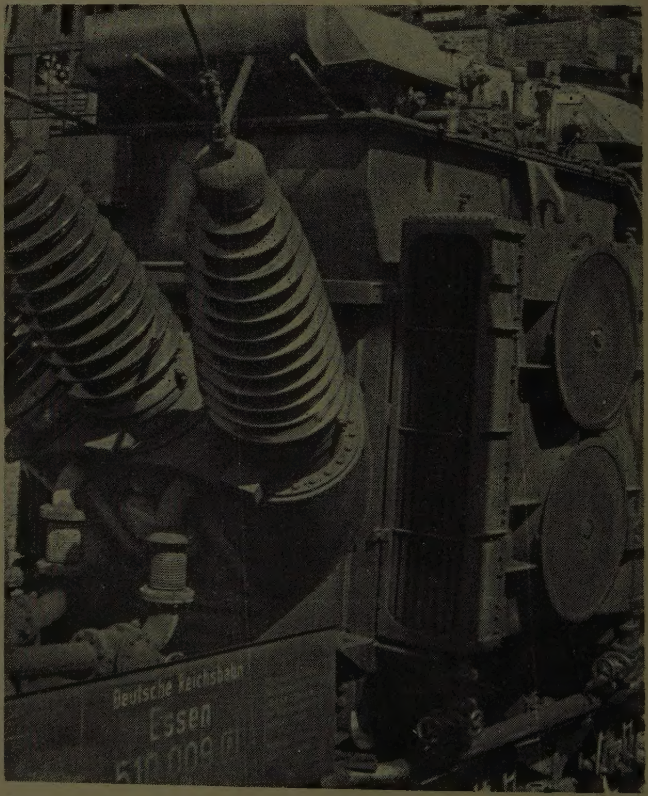

Figure 3. Tank bottom-mounted bushings on a 60-megavolt-ampere portable transformer

Table II. Capacity and Generating Comparison Between the United States and the German Electrical Utility Industry

	United States[3]		Germany	
	1937	1944	1937	1944
Peak load in per cent of available capacity	68.2	82.5	68.2	75.5
Maximum demand in per cent of available capacity	68.2	82.5	68.2	93.4
Use factor in terms of available capacity, per cent	38.0	53.0	34.2	51.4
Available capacity per inhabitant, kw	0.274	0.372	0.116	0.123
Energy consumption per inhabitant per year, kwh	911.0	1,720.0	347.6	554.2

		1937	1944
1.	Ratio: available capacity per inhabitant U. S. available capacity per inhabitant Germany	2.36	3.02
2.	Ratio: kw/inhabitant/yr, U. S. kwh/inhabitant/yr, Germany	2.62	3.10
3.	Ratio: population U. S. population Germany	1.83	1.68

breaker is open, the two contact arms are separated by a free air space approximately 70 per cent of the ground clearance. To close it, the two contact arms are rotated to bring the two butt contacts together. The air blast begins when the contact separation approaches striking distance and stops when the contacts touch. On opening, the air blast starts immediately before the contacts begin to separate, and it persists until slightly after the contacts have reached their open position. Air pressures up to 250 pounds per square inch are used. The arc interruption takes place in the unconfined air blast from both nozzles.

This circuit breaker was praised highly for its simplicity, and freedom from trouble, as well as its ease of maintenance.

In addition to the three types of air blast circuit breakers for the 110- and 220-kv circuit voltages, there was one type of multibreak oil-poor circuit breaker, made by Voight and Haeffner.[5] In the circuit breaker types 1 and 2 and in the oil-poor high-voltage circuit breakers, resistors were used to assist in the interruption of line charging current. These were generally of relatively high ohmic value, approximately 2,500 ohms, and were built with water conductors and ceramic conductors. Considerable difficulty was experienced with them, and their development had not reached a satisfactory stage.

In the medium voltage classes, the air blast circuit breakers were greatly preferred over oil-poor and water circuit breakers, and development work practically was confined to air-blast types.

Circuit breakers were found with ratings up to 1,500 megavolt-amperes in the voltage classes up to 30 kv and up to 2,500 megavolt-amperes in the 110- and 220-kv classes. Very little information was obtained on rates of recovery voltage rise, but, judging from circuit arrangements only, relatively low recovery voltage rates could have existed. Facilities available for factory testing of circuit breakers were limited to about 600 megavolt-amperes capacity, and records indicated that some field tests had been made up to interrupting duties of 1,800 megavolt-amperes (calculated values).

POWER TRANSFORMERS

In the older generating stations and substations, oil-immersed water-cooled 3-phase transformers were frequent. The oil coolers were submerged in a water tank, so that the water level was well below the bottom of the transformer tank, and no leak could contaminate the transformer oil. Oil circulating pumps were provided.

Newer installations had forced-air- and forced-oil-cooled transformers, which were standardized in the 30, 60, and 100 megavolt-ampere sizes. These units were built integrally with 8- or 12-wheel railroad cars for instant portability. The high-voltage bushings were located near the bottom of the tank, so that they could remain in place during transportation (Figures 3 and 4).

In the 220/110-kv ratings, the 220-kv and 110-kv windings were insulated fully and Y-connected for use with Petersen grounding devices. A 10-kv tertiary winding, delta-connected, was used for harmonic suppression and for connection of shunt reactors. Tap changing under load was used where required, although equipment for this was available only in the most recent designs. The high-voltage windings were shielded and all high-voltage bushings were gapped.

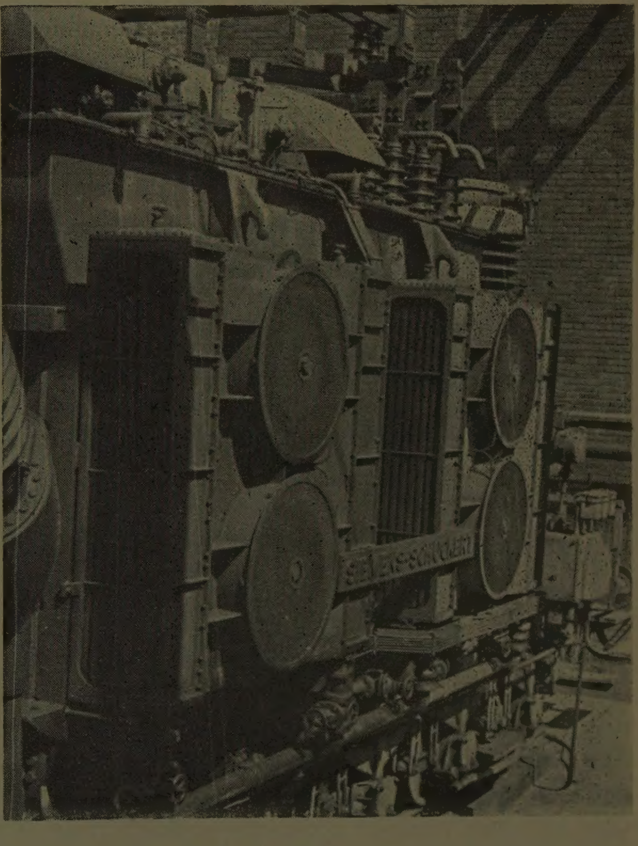

Figure 4. Forced-oil–forced-air coolers on a 60-megavolt-ampere portable transformer

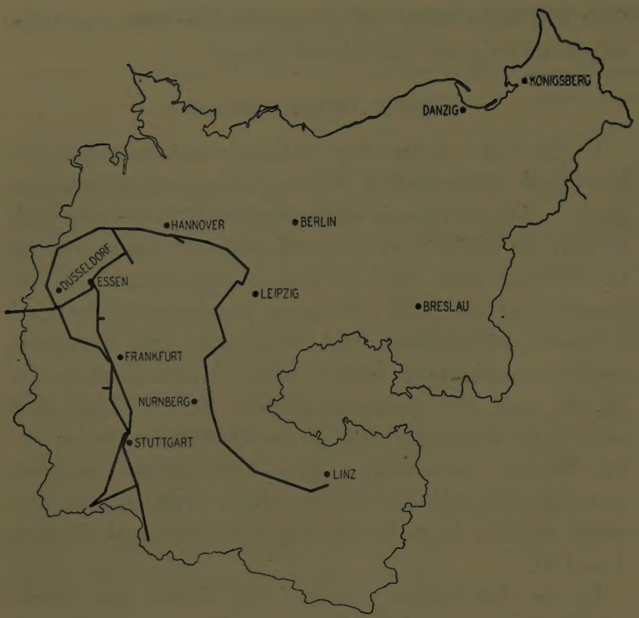

Figure 5. Map of the 220-kv transmission system of Germany

For connection between generator voltages and either 110 kv or 220 kv, similar transformer designs were used, with the low-voltage winding delta-connected.

Very high noise level on some of the latest transformers revealed that in these designs very high flux densities, up to 14 kilogauss rms, were used. This resulted also in high exciting current and high harmonic content. The high exciting current was not considered a disadvantage, as even at maximum load some shunt reactance was required. The high harmonic content did lead into some difficulties with telephone interference and with tuning of Petersen grounding devices. To control this, such high density transformers were dispersed.

Buchholz relays were used universally on transformers with differential relays as backup. No askarel transformers were found.

TRANSMISSION FACILITIES

The backbone of the interconnected transmission system was a double-circuit 220-kv system in the shape of an inverted U (Figure 5). Starting in southwestern Germany, the western leg collected the power production of the river plants in the upper Rhine River and that of the Schluchsee natural and pumped-storage development. A branch collected the generation from high-head developments in the Austrian province of Vorarlberg.

On the northward leg, this line, which for a large part of its run was paralleled by a third circuit, collected and supplied interconnected private and municipal plants. At Brauweiler, near Cologne, and at the Koepchenwerk, near Essen in the Ruhr area, both of which were principal switching points, a loop, consisting of a single circuit line, encircled the Ruhr–Rhineland industrial area. From the northernmost point of the loop a double circuit line interconnected via 110-kv circuits with the Berlin area.

A principal interconnecting point was the Marke substation, near Leipzig, from which the 220-kv system, again as a double circuit line, ran to Linz.

Transmission capacity varied from point to point. It was between 300 and 400 megavolt-amperes for a transmission between adjacent major interconnection centers. This 220-kv system was not, however, operated as one system, chiefly because of the lack of means for controlling power flow; instead it was used for energy interchange between major interconnecting points, so that in fact the German utility system was operated electrically in 5 to 6 independent, nonsynchronized parts.

Frequently a generating plant supplied a local area with several generating units, while other generating units were connected to the 220-kv system. As damage to generating plants mounted, attempts were made to operate large sections in synchronism, and it was found that swings created by non-co-ordinated load changes often overloaded the lines to a point where they separated. The lack of phase angle regulating transformers prevented operation of closed loops.

While automatic frequency control equipment was available on some systems, with tie line bias control on still fewer systems, a co-ordinated system of automatic frequency and tie line control did not exist. The RWE system, which comprised the western leg of the inverted U, was operated completely with manual control of frequency and tie line loading.

An additional reason for operating in nonsynchronous parts was the grounding system. For instance, the RWE 220-kv system had to be electrically separated at Brauweiler and at the Koepchenwerk during faults, so that the residual arc current for line to ground faults became low enough for self-extinction of flashover arcs.

Resonant grounding was used universally on the 220- and 110-kv lines and even on a 66-kv cable system. Relaying was provided to separate the 220-kv system into smaller units on faults for two reasons:

1. To reduce circuit breaker interrupting duties.
2. To reduce the residual arc current on line to ground faults.

In some instances, synchronism between parts was maintained by high impedance ties through the 110-kv system. This imposed a severe limitation of transmission capacity as the high impedance ties often separated because of instability. These limitations imposed serious handicaps after large blocks of generating capacity had been disabled.

Carrier current was used widely for communication purposes and rarely for relaying.

DISTRIBUTION

Most of Germany was provided with a service voltage of 220/380 volts. Service was practically all radial, except in the largest cities, where low-voltage network distribution was gaining favor. Network sections were kept small, between 20 and 30 megavolt-amperes; although in Berlin, sections as large as 70 megavolt-amperes existed. Network transformers were used in sizes from 160 to 250 kva with 6-kv primary feeders in the earlier installations and 30-kv feeders in the latest. Relatively high reactance performers (7.5 per cent) were used, and the total reactance from the substation bus was kept high, thus holding the short-circuit currents to low values but necessitating the frequent use of synchronous and static condensers. The use of static capacitors was gaining in the later years.

The network protectors were mostly pilot-wire-operated for opening on primary faults and by voltage relays or pilot wire for closing. Fuses of a special design, capable of interrupting 25,000 amperes at 400 volts, were used as backup protection. Buchholz relays were used universally on distribution transformers for network use.

PROTECTIVE MEASURES AGAINST WAR DAMAGE

With the beginning of the war, personnel shelters were built in two types: for the protection of essential operating personnel at their posts, and mass shelters for other plant personnel and office forces. For essential plant personnel, individual shelters were provided (Figure 6). Sometimes these were equipped with instruments for the supervision of most important plant functions, such as steam pressure, boiler feed water pressures, voltage, and frequency. In plants built during the war such shelters were integral with the turbine or generator foundations and smokestack foundations, elaborate instrumentation was provided, and remote controls were furnished.

For less essential personnel and their families mass shelters were provided under foundations and in the form of specially built cone-shaped concrete towers with 9-foot-thick walls, up to 6 floors in height. In the base of the structures, emergency communication equipment, supervisory instruments, and controls were located.

Most frequently observed for the protection of rotating machinery were portable concrete structures, built in the cross-sectional shape of the letter A, reinforced and provided with lifting eyes and handling by means of cranes. These structures were 8 feet high and approximately 3 feet wide, with interlocking points to permit assembly into walls. Roofs frequently were found over turbogenerators. Semicircular, reinforced concrete shields also were used (Figure 7).

Operational measures were taken during air alarms, such as isolation and sectionalizing of steam pipes, boiler feed pipes, and circulating water piping. As the load dropped during an air attack, electric machinery was quickly taken off and de-energized.

For large power transformers protective measures consisted of loose brick or cinder blockwalls, built one to

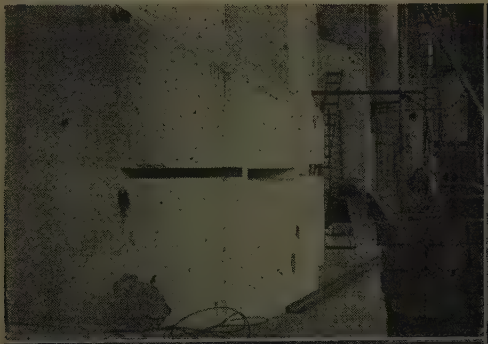

Figure 6 (upper left). Concrete personnel shelter in a turbine room

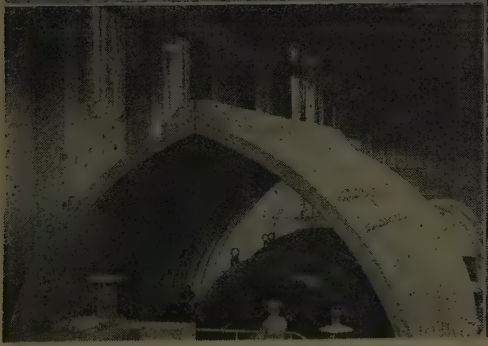

Figure 7 (lower left). Sectional reinforced concrete shelter for a 32,000-kw hydroelectric turbogenerator set

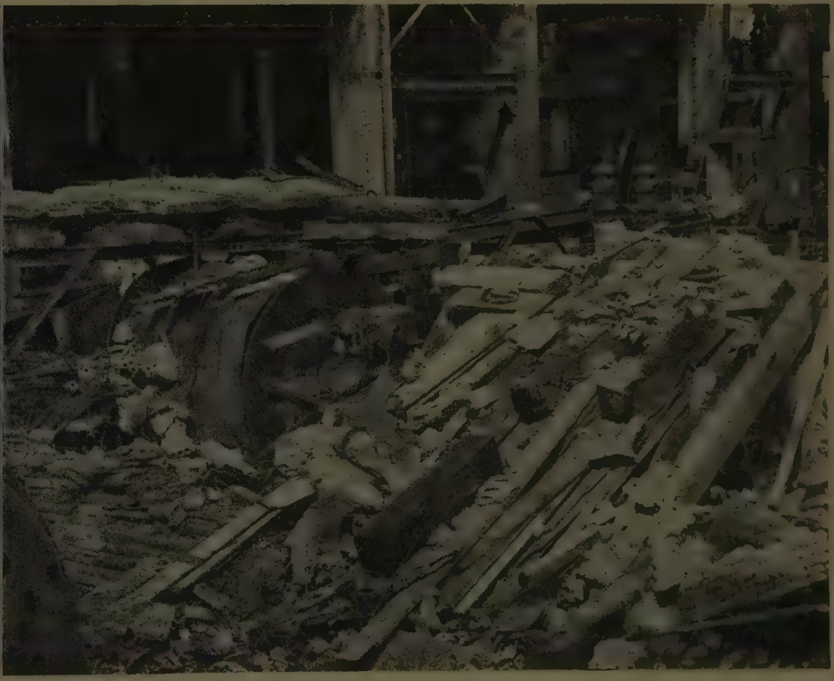

Figure 8 (right). Heavy bomb damage in a turbine room

Table III. Analysis of Generating Capacity and Generation of the German Electrical Utility Industry[2,8]

	1937				1944			
	Generation		Capacity		Generation		Capacity	
	Million Kwh	Per Cent	Mw	Per Cent	Million Kwh	Per Cent	Mw	Per Cent
Thermal plants using hard coal*	10,124	37.0	3,860	42.3	20,792	46.0	6,080	45.7
Thermal plants using brown coal†	11,382	41.6	2,810	30.8	14,916	33.0	4,420	33.2
Hydro plants	4,846	17.7	1,860	20.4	9,492	21.0	2,460	18.5
Miscellaneous	1,027	3.7	600	6.5	**	**	340	2.6
Totals	27,379	100.0	9,130	100	45,200	100	13,300	100

** Included in line 1. *Bituminous and anthracite. † Lignite, peat, and the like.

Table IV. Distribution of Plant Sizes[2]

Plant Size, Mw	Hard Coal	Brown Coal	Hydro	Miscellaneous	Total
Over 200	1	4	0	0	5
100–200	22	12	6	0	40
50–100	24	9	14	3	50
	47	25	20	3	95

The capacity of these of 95 plants was 12,145 mw.

two feet higher than the transformer tank. Earth embankments were thrown up between transformers to prevent spreading of oil fires.

All these measures limited the amount of damage and were highly effective against occasional low saturation raids. Only during highest concentration raids were plants consistently shut down for prolonged periods (Figure 8).

One underground plant built in 1940 was found in Mannheim, with a capacity of 30,000 kw obtained from a 1,620 pounds per square inch 925-degrees-Fahrenheit boiler and turbogenerator, of which the generator voltage was 22 kv. The whole plant, excluding coal handling, was built in a circular concrete caisson, 100 feet in diameter, 75 feet deep, with 6-foot-thick walls and a 10-foot-thick roof, the upper surface of which was 10 feet below grade. A heavy bomb hit close by severely damaged the turbine by earth shock.[2,5,6]

WAR DAMAGE EXPERIENCE

War damage experience can be illustrated best in terms of the experience of the RWE system, for which system a rather complete report is available.[5]

From the beginning of the war up to the spring of 1943, damage to the German electric utility plant was confined principally to line damage, from falling antiaircraft shell splinters and trailing anchor cables from errant antiaircraft barrage balloons.

Particularly sensitive to falling antiaircraft shell splinters were the aluminum-steel-core 110-kv and 220-kv conductors, strands of which were easily cut and when cut, unravelled, causing line-to-ground and line-to-line short circuits. Anchor cables of errant barrage balloons caused short circuits and even burn-off of conductors.

From 1942 on, additional line damage was due to direct blast damage of line structures, conductor damage by bomb splinters, and insulator damage due to direct and transmitted bomb blast effects. During 1942 there occurred on the RWE system 259 cases of line damage on 110-kv and 220-kv lines by war action, of which 49 cases were due to barrage balloons. In a single day 43 cases of line damage occurred.

Up to the end of 1942 no serious damage had been done to power plants, and there had been no serious interference with the production and transmission of electric power.

With the beginning of 1943 came concentrated air attacks against selected industrial plants and the first concentrated area attacks upon whole cities. Line damages to the amount of 197 cases occurred for the first $3^1/_2$ months on the RWE system alone. An area attack upon the city of Cologne severed 43 110- and 220-kv lines, isolated the southern half of the RWE system, and interrupted the connections between the 450,000-kw Goldenberg plant and the Brauweiler substation. The system lost 360,000 kw of generating capacity, which was made up by emergency transfer of 340,000 kw over undamaged 220-kv lines. This attack occurred on a Saturday; by Monday all essential lines had been repaired and restored to service.

March and May 1943 brought the first concentrated area attacks upon the Ruhr area and the city of Essen. These created severe damage to underground distribution facilities, which from that time on never could be restored completely. Restoration efforts were directed principally to the re-establishing of service to industrial plants and other essential consumers. As most of such essential consumers were radially fed, restoration was accomplished quickly. Repairs to the low-voltage network were slow and difficult, and finally, after repeated attacks, were abandoned completely.

Up to that time the generating plants were loaded to capacity and the curtailment program was in effect to limit the demand over peak hours. The destruction of customers' industrial plants eased the load situation, so that the electric power plants were relieved somewhat.

In May 1943 came the celebrated attacks upon the Möhne and Eder dams. The loss of the Eder dam resulted in a capacity loss of 120 megawatts for 8 months, due to damage of the hydro plants associated with this dam. As this development was a pumped-storage plant, its loss was particularly severe. The loss of the Möhne dam, which had no hydroelectric plant directly associated with it, resulted in the loss of the Koepchenwerk pumping plant and a number of smaller plants along the Ruhr River by flooding, amounting to approximately 200 megawatts loss for 4 to 6 months.

From that time on, until May 1944, approximately

300 megawatts of German capacity were unavailable as a result of war action.

From May 1944 on, sharply increased attacks resulted in rapidly increasing outages due to damage of plant facilities. Beginning with a capacity loss of 700 megawatts in May 1944, the capacity loss reached 1,900 megawatts by the end of October. That date was the beginning of cessation of co-ordinated operation. Even up to that date, however, destruction of consumer plants kept apace, so that the remaining plant capacity was able to supply the remaining demand with varying degrees of curtailment. After October 1944, one no longer can speak of a co-ordinated utility system.

Although official records stop with the end of October 1944, giving a total loss due to direct war action of approximately 1,900 megawatts, and although an official German statement gives the loss due to war action for January 1945 as 3,110 megawatts, the actual loss of capacity for the public utility system at the end of the war was probably between 5,000 and 6,000 megawatts, without counting as loss the unavailability of plants because of occupation.

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Large Rectifier Station Practice

THE use of the mercury-arc rectifier to supply large amounts of direct current required in electrochemical and electrometallurgical industries has received considerable impetus in the last several decades by many new installations by large companies. Operating experience and installation details as described by representatives of four companies provide interesting material for comparison.

Station Design

D. I. BOHN
MEMBER AIEE

INSTALLATION and operating experience gathered from many rectifier stations during World War II are the basis for the following comments. Some of these features were employed in these wartime stations and a number of additional suggestions are based on operating experience. The proposed station would consist of one or more units, each unit having 12 5,000-ampere 650-volt ignitron or excitron rectifiers, six rectifier transformers, and all necessary switchgear, phase shifting transformers, and auxiliaries.

RECTIFIER COOLING

It is believed advisable to eliminate a cooling water supply for the station, to be done by using water-to-air heat exchangers and air-cooled high-vacuum pumps. From a cost angle, the expense of providing a reasonably positive cooling water supply in many cases more than makes up the difference in first cost between water-to-water heat exchangers and water-to-air heat exchangers. The greatest advantages from the water-to-air installations result from the almost zero maintenance cost.

The possibility of freezing is taken care of by employing an alcohol base antifreeze, in whatever proportion the lowest expected temperature indicates.

Two general types of cooling fans are provided. In one type, a 2-speed 15-horsepower squirrel-cage motor drives a centrifugal fan. Half speed operation using about four horsepower actually was used for better than 80 per cent of the hours per year, so that the cost for fan power is a very small item. A pair of automatic temperature-controlled valves operate to throttle and by-

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Based upon papers presented at the conference on operation of mercury-arc rectifiers, June 13, 1947, held during the AIEE summer general meeting, Montreal, Quebec, Canada.

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pass rectifier cooling water simultaneously to maintain constant rectifier temperature.

Another type of heat exchanger has nine fractional horsepower fans, and the operator can run either three, six, or nine of these fans, as desired. Both types have been eminently satisfactory and would be considered for a new installation.

HIGH-VACUUM PUMPS

Although the amount of cooling water required to supply a water-cooled high vacuum pump is an extremely small amount, its failure, nevertheless, can shut down an entire station. For this reason air-cooled high vacuum pumps are recommended.

RECTIFIER CIRCUIT BREAKERS

The use of high-speed anode circuit breakers justified itself thoroughly in these wartime stations. In most installations, high-speed anode circuit breakers will keep the maximum anode current to a figure below 50,000 or 55,000 amperes. usually around 40,000 or 45,000 amperes. If only a high-speed cathode circuit breaker is employed, these peak anode currents will be increased about 15,000 to 20,000 amperes.

Experience has been gained in stations employing a slow (semihigh speed) cathode circuit breaker, and none of the anode circuit breakers have been known not to function when called upon to do so. However, this is always a possibility and consideration should be given to installing high-speed cathode circuit breakers as well as high-speed anode circuit breakers in a new station.

For a conversion unit of this rating, it is preferred that a backfire open all six poles of the anode breaker supplying the backfiring unit. With a large number of rectifiers in parallel supplying the load of one unit, there is no particular object in providing opening and closing of individual anode circuit breaker poles.

ADDITIONAL SWITCHING

Each of the six rectifier transformers is connected to a twin 13-kv bus by means of two gang-operated disconnect switches which can open magnetizing current of the transformer. A single main oil circuit breaker or air blast circuit breaker feeds either or both of the transformer busses, and trips the entire conversion unit in the event of transformer or bus faults. Both positive and negative rectifier disconnects are provided.

RELAYING

The relaying is kept quite simple, although adequate. Care should be taken to see that the rails supporting the rectifier transformers are not grounded solidly through steel to the station ground bus. A single low ratio current transformer connected between each transformer case and the ground bus supplies an instantaneous relay which will trip the main breaker feeding the conversion unit. The main circuit breaker is provided with instantaneous and inverse time overcurrent tripping through its own bus current transformers.

ADDITIONAL FEATURES

Mention is made of the following general features, most of which have been employed in recent stations of Alcoa.

1. The station is built with two floors, probably with the lower floor at ground level. The lower floor, however, does not contain any equipment necessary for operation. It, therefore, is virtually empty except for the air filters and fans, control cables, and anode cables.

2. Air washers and fans supply cooling air to the lower floor, and grills around the rectifiers permit it to flow into the second floor and out the roof.

3. Both front and back walls of the station are covered up quite well with busses and equipment, and therefore no windows of any sort are employed.

4. Very few conduits are used, all control cables being carried between rectifier cubicles and the main vertical-type switchboard in cable troughs.

5. Special attention should be given to mercury baffling in rectifiers, as this has been an important cause for backfires, and some of the baffle designs which have been used to prevent this have not been too satisfactory.

6. Individual rectifier voltmeters are unnecessary, and one or two bus voltmeters are all that are needed.

7. No underground power cables of any sort are employed.

8. Up to and including four of these conversion units are controlled with one operator at one switchboard.

Operation in Aluminum Plants

J. W. WARD

TOTAL rectifier connected load of the Arvida Works Aluminum Company of Canada, Ltd., is 747,000 kw. Of this total 174,000 kw is supplied by multianode tank rectifiers, and 573,000 kw is supplied by single anode per tank ignitrons. Each unit of all types is made up of one transformer, and two tanks—in the case of the multianode single tank type—or two frames in the case of the ignitron.

The incoming 154-kv 3-phase 60-cycle power is stepped down to 13.2 kv at which value the primaries of the rectifier transformers are energized. Normal d-c output of the rectifiers is 700 volts for most of the plant, the remainder is 575 volts. Taps on the transformers permit a variation in direct voltage of 20 per cent on the majority. By means of grid control the direct voltage of the multianode type can be regulated on any transformer tap. The practical limit of this control is 6–8 per cent.

With the ignitron, voltage reduction can be obtained on any transformer tap by delaying the time of ignition. The maximum practical limit of this reduction is set at 15 per cent, but in either case when the afore-mentioned limits are approached the backfire rate usually becomes objectionable.

Transformer taps are set so that a minimum of voltage reduction by this means is required. Associated with voltage reduction by grid or ignitor circuit control is a reduction in power factor which is avoided as much as possible.

With no voltage suppression and normal transformer tap setting, the power factor on the 13.2-kv bus is between 92 and 93 per cent. The efficiencies obtained are very close to those calculated by the manufacturers. For the multianode type this value varies between 93 and 93.5 per cent. For the ignitron this value becomes 95–95.2 per cent.

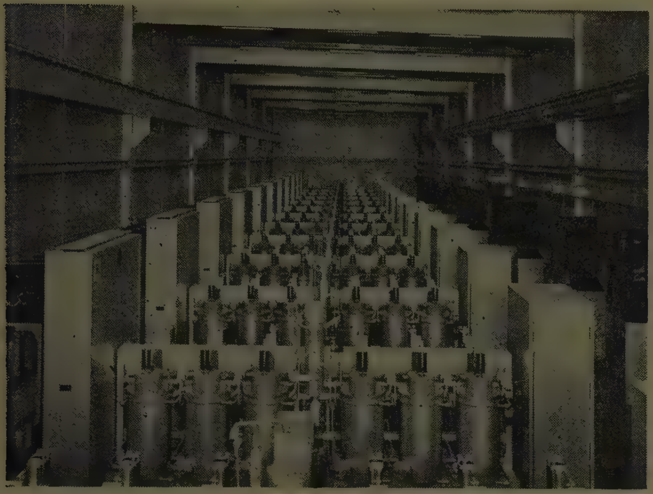

Figure 1. Ignitron installation in large electrochemical plant

IGNITRON EXCITATION

In 1941 the first ignitron installation of any size in Canada was made at Arvida. This was before the static excitation circuit had been developed fully for use in ignitrons. Energy to the ignitor tip was provided by impulse generators, which consisted of a generator driven by a synchronous motor and equipped with windings designed to give a short steep impulse to the ignitor at the proper point of the main positive half cycle.

This system worked quite satisfactorily as long as the power supply was stable, but any change in frequency caused a change in the relative phase positions which produced a cumulative and very disturbing swinging effect in the load. With the introduction of the static excitation circuit consisting of the properly co-ordinated resistors, reactors, capacitors, and rectifiers this trouble disappeared.

By means of a variety of connections involving the primary windings of the individual rectifier transformers, the Arvida system, when all units are working, is broken down into 96 phases. Until the number of phases used exceeded 12, telephone interference was objectionable.

PERSONNEL AND MAINTENANCE

The load at Arvida fed by rectifiers is divided into three groups, with a separate station for each group. The first building houses 15 units or 30 tanks with a total capacity of 90,000 kw. These units are controlled from one board manned by one operator with a floorman as assistant. This gives a direct annual operating cost of $178 per megawatt. The second station houses 34 units with a total capacity of 232,000 kw. There are three control boards in the center of the building so that one operator and his floorman look after the whole installation. Operating cost, not including supervision, for this station is $69 per megawatt per year. The largest of the three stations houses 60 units, and a total capacity of 420,000 kw. There are four control boards, with one operator per board and one floorman for each two boards. In this station the operating cost is $117 per megawatt per year.

The maintenance force required consists of one man per six rectifier units and one foreman over all. For the years 1943 and 1944 when production was at its maximum the average maintenance cost per 1,000 kw installed, including labor and material, was approximately $69 per year. On the same basis the maintenance cost for our 79,000 kw rotary converter installation was approximately $223 per year per megawatt capacity.

The principal parts requiring maintenance are vacuum pumps, high-speed circuit breakers, ignitors, tanks which must be opened and cleaned when backfire rate becomes excessive, and heat exchangers in which scale forms.

BACKFIRES

There is a wide variation in the frequency of backfires between units. In spite of all efforts no panacea has been found. Generally speaking the number of backfires per unit per month are much lower for the multianode type than for the ignitron. For the month of April 1947 there were 0.75 backfires per unit of multianodes as against 8.0 for ignitrons. Considerable improvement has been achieved in the backfire rate of the multianode rectifiers. After the original installation and elimination of the principal difficulties the average rate was approximately 6.0 backfires per unit per month, whereas the rate for the ignitrons has been as high as 12.7 per unit per month. Many units of both types for long periods do not backfire at all.

One station was equipped with both 25- and 60-cycle generators, and the rectifiers were designed to operate on either frequency, depending upon which was available at any given time. A lower backfire rate on 25 cycles as compared with 60 cycles, because of the lower frequency, was to be expected, but the actual over-all ratio between the number of backfires on 60 cycles as compared with 25 cycles was much higher than the ratios of the frequencies, indicating that other factors must have been involved. One of these factors might be the difference in available time for deionization on the lower frequency.

The usual procedure followed in the case of the ignitrons, when a unit begins back firing abnormally, is to locate the offending tank by means of surge indicators, after which it is unloaded, opened, and cleaned. The ignitor tip is checked and if wetted it is discarded. All other removable parts are taken out and cleaned. All metal parts including the inside of the tank are sandblasted. Damaged parts are replaced and the mercury is reconditioned. Great care is exercised in preventing oil, perspiration, or any other foreign material from collecting on parts, otherwise a plague of backfires is likely to result. All renovated tanks are degassed on a frame used for this purpose before being put back in service.

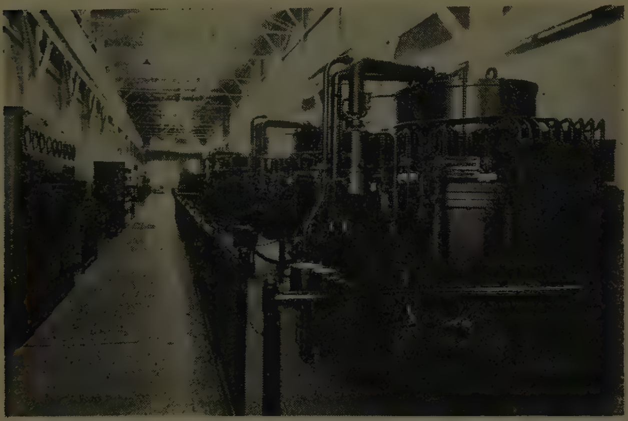

Figure 2. Rectifier room at hydrogen plant of Consolidated Mining and Smelting Company of Canada, Ltd.

THE MULTIANODE TANK

With the multianode type it is necessary to dismantle the whole unit, which, while resulting in much more work than for a single ignitron tank, happens very infrequently. Some of these tanks have operated three and four years before being dismantled.

The first multianode tanks installed about ten years ago were equipped with rubber gaskets. After four or five years of service these tend to crack and leak. In this type also we have found that all porcelain insulators inside the tank after a few years service become coated with mercury which it was discovered could be evaporated off by placing the porcelain parts in an oven for several hours at a temperature which is just below red heat.

On a large power system excessive short-circuit stresses develop in rectifier transformers, so that coil bracing is of paramount importance. No anode circuit breakers and only one high-speed cathode circuit breaker per frame or tank, plus an oil circuit breaker ahead of the unit transformer, have been used in this installation. Anode circuit breakers might have prevented some of the transformer failures when they were first installed, however, none of the more ruggedly designed transformers have failed, and those which did break down and were rebuilt with extra bracing between coils have stood up without failure. With anode circuit breakers installed, a slow-speed cathode circuit breaker could be used and the unit oil circuit breaker could be replaced by high-capacity fuses.

It would appear that with properly designed equipment backfires have been relegated to the position of mere nuisances. Where a number of units are used in parallel no production is lost. However, for the benefit of those who might be in the immediate neighborhood, it would be well to dispense with the noise and the fireworks associated with arc-backs.

Operation in Metallurgical and Chemical Plants

A. G. DICKINSON
MEMBER AIEE

CONSOLIDATED Mining and Smelting Company of Canada, Ltd., metallurgical and chemical plants, located at Trail, British Columbia, have a total load of 180,000 kw of which 80 per cent is converted to direct current for use in electrolytic processes. The first rectifier installation went into operation in 1929. Further installations have been added and now 70 per cent of the installed conversion equipment consists of mercury-arc rectifiers.

RECTIFIER EQUIPMENT

There is a total of 14 6- and 12-phase rectifiers installed, each rated at 10,000 amperes and with one exception each operates on a separate load. Twelve of the units consist of two 5,000-ampere multianode cylinders operating in parallel and fed from one rectifier transformer. There is one ignitron unit with 24 tanks arranged 12 per frame and one glass bulb rectifier with 48 bulbs. These units vary from 560 to 830 volts according to requirements. Direct voltage regulation is provided in each case by means of a voltage regulating transformer, or transformer taps. Grid voltage control is installed on some of the units.

Up to 1929 the direct current required for the zinc plant electrolytic cells was supplied by motor-generator sets and rotary converters. Rectifiers were coming into prominence in electric railway work as well as d-c networks in cities. From their performance they gave indications of being suitable for electrolytic work, although few installations of any appreciable size were in operation at that time. As the result of study, rectifiers were decided upon and three 5,600-kw 6-phase units were installed. It was found that some changes were necessary in the original rectifiers supplied in order to carry the continuous rated load. Some of the changes included the installation of grid control, high-speed d-c circuit breakers, and closed circuit cooling.

The fertilizer plant started operation in 1931. Hydrogen used in making ammonia is obtained from the electrolytic decomposition of water. Power is supplied at 60,000 volts 3 phase and is converted to direct current by means of mercury-arc rectifiers. Transformers are installed outdoors and the metering is done on the d-c outgoing bus. Provision is made in the d-c switching to insert a water rheostat in the circuit when putting the unit on load. The same rheostat also is used when depolarizing the gas cells, before the circuit breaker provided is closed, to put a short circuit across the cells. As in the case of the first zinc plant rectifiers, some modifications and changes were made in these units and since then the units have operated satisfactorily at full load.

All the units operate on separate groups of gas cells except two. A transfer bus is arranged so that a Hewittic glass bulb unit can be used as a spare for any cell group.

On all six of the original rectifiers the d-c circuit breakers supplied were the standard normal-speed type. High-speed relays were used to apply negative voltage to the grids for arc suppression when backfires occurred, but since the negative grid voltage could not function until the d-c backfeed was interrupted it was decided to install high-speed d-c circuit breakers in the cathode connection of each 5,000-ampere rectifier cylinder.

GRID VOLTAGE CONTROL

The original zinc plant rectifiers were not provided with energized grids but these were installed later. The first three hydrogen plant rectifiers had energized grids but not grid voltage control. Rectifiers purchased later were equipped with grid voltage control with one exception where it was not available. Grid voltage control is used only for putting the units on load to get added voltage regulation.

Only one of the original six rectifiers was equipped with a closed circuit cooling system which comprised a water-to-water heat exchanger and circulating pump. The other five units had straight tap water cooling but operating experience indicated that the closed circuit cooling was a decided advantage and changes were made accordingly.

Tests made in 1929 on the original zinc plant rectifiers gave an over-all efficiency of 93.5 per cent and a power factor of 92.25 per cent (taken on 13.2 kv supply). The guaranteed efficiency of the various units installed ranges from 93.2 to 95.7 per cent.

Since the first six rectifiers were to operate on electrolytic zinc and hydrogen cells, it was specified that the direct current derived from these units would be as effective for electrolytic purposes as if the a-c power had been converted into direct current by means of a 60-cycle rotary converter. Five of the original units are 6 phase with a d-c reactor to smooth out ripple, and the other unit is 12 phase. Both of these arrangements have worked satisfactorily and are now in general use in our plants.

An effective 24-phase system to counteract harmonics is planned, and part of the load already has reached this point. Unfortunately, due to the nature of the processes, the plant is unable to keep a balanced load in continuous operation.

PERSONNEL AND MAINTENANCE

The average total yearly cost of operation, maintenance, and repairs for the past five years for the zinc plant rectifiers was \$0.72 per installed kilowatt, and for the hydrogen plant rectifiers was \$0.67 per installed kilowatt. Operating costs account for about 55 per cent of these figures, and maintenance and repairs the rest.

The average time lost due to the maintenance and repair of rectifier equipment for the past five years for the zinc plant rectifiers was 3.4 per cent and for the hydrogen plant rectifiers was 1.1 per cent of the total time lost. The figures do not take into account the time lost when units were down for causes other than maintenance and repair of the rectifier equipment.

A large part of the difference in lost time between the zinc plant and hydrogen plant is due to the fact that in all the double cylinder units in the hydrogen plant, arrangements are made to take one cylinder off load for repairs or overhaul while the other cylinder stays on load giving 5,000 amperes for the unit. In the zinc plant only one unit is equipped this way and for the other three the whole unit goes off load.

Regular maintenance work is carried out on all equipment. Water jackets are cleaned out periodically but the vacuum chambers of the rectifiers are not opened unless there is some indication of trouble. Just prior to the war it was decided that five years was probably the limit to operate a metal tank type of rectifier without opening it for inspection and overhaul. During the war, to get the maximum output possible, it was decided to operate the rectifiers as long as they would carry full load satisfactorily. Two units were not opened for seven years, but this was the maximum obtained. After an opened cylinder is closed it has to be "formed" or "degassed." This is done by operating the vacuum pumps and gradually warming up the rectifier, then putting it on light load at reduced voltage. Load is increased gradually as vacuum conditions permit. The usual time taken for "forming" a rectifier is from three to six days. Particular stress is laid on giving the rectifier a good "forming" after it has been opened.

Operation and maintenance is carried out under the direction of a senior supervisor. In the hydrogen plant rectifier room a senior and junior operator work on each shift, also two power servicemen and one helper work on day shift only, under the supervision of a foreman. Extra help when required is supplied from the zinc plant.

BACKFIRES

There are a number of causes for backfires such as incorrect operating temperature, poor vacuum, and broken or dirty insulators. There are also the odd, or random backfires which happen at irregular intervals and for no apparent reason. The number of backfires occurring on a unit are used as one of the important indications as to its general condition and as to whether or not the cylinder should be opened for inspection.

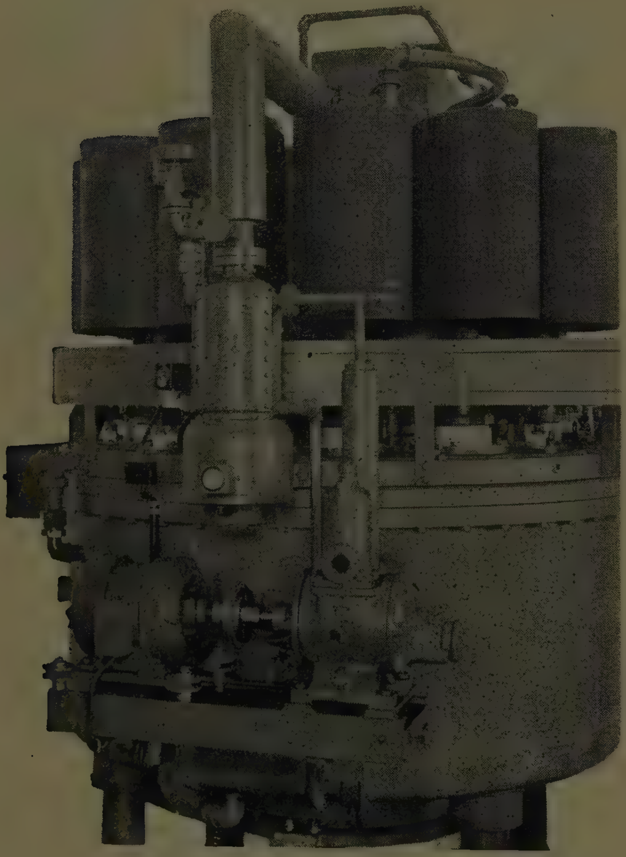

Figure 3. Evacuating equipment built on multianode mercury-arc rectifier

The average number of backfires per unit per year during the past five years for the zinc plant was 47 and for the hydrogen plant was 44. One unit operated over five years without a backfire, but also there have been about 20 backfires on one unit in one day.

In operation it is the practice to switch the whole unit off load when a backfire occurs. The one exception to this is the Hewittic glass bulb unit in which one section of bulbs only is cut out of service.

HEWITTIC GLASS BULB RECTIFIER

As previously mentioned, there is installed one 8,300-kw Hewittic glass bulb rectifier. The unit as originally supplied consisted of 40 bulbs operating in parallel and fed from a 6-phase winding on the rectifier transformer. The bulbs are connected to a main d-c bus through five 3,000-ampere high-speed circuit breakers equipped with reverse current trip. These in turn feed three 4,000-ampere high-speed circuit breakers operating in parallel and equipped with overcurrent trip. High-speed high rupturing capacity fuses are installed in all anode leads. The main rectifier transformer steps down from 60 kv to rectifier voltage and also contains taps to give a 22 per cent over-all voltage range. A d-c reactor is installed in the negative bus. Some changes were made in the original installation which included the addition of eight more bulbs.

Temperature limits of a minimum 10 degrees and a maximum 38 degrees centigrade were set for cooling air entering the cubicles. Since the changes and modifications were made some years ago the unit has operated satisfactorily at full load.

The unit went on load January 1942 with 40 bulbs installed. Eight more bulbs were added in 1943 and bulb replacements dropped appreciably after that.

Operation in Mines

C. G. MARSHALL

PRODUCTION of 20,000 tons of coal daily is procured by the use of highly mechanized mining methods in the Tennessee Coal, Iron and Railroad Company. With the exception of main pumps used for mine drainage all underground equipment is operated from a 250-volt d-c grounded system. The total connected capacity of the conversion equipment at the company's five mines is 8,600 kw.

In typical mechanical mining a conversion equipment substation is located adjacent to a load center and serves several operating units, each unit consisting of tools and transport facilities. There may be several such load centers distributed over a wide area but connected with each other through feeder cables. A characteristic of mining operations is that the load centers move away from the conversion equipment, and there are frequent high peak loads.

One of the most important requirements for successful mechanical mining is a good power supply. To fulfill this requirement conversion equipment of sufficient capacity must be located carefully at the load centers together with sectionalizing circuit breakers to insure uninterrupted service and to maintain sufficient voltage for efficient equipment operation.

INSTALLATION

Previous to 1943 the conversion equipment consisted of synchronous and induction motor-driven motor generator sets, and two steam-engine-driven generators used as standbys.

During 1943 when additional coal was needed, a new mine was opened. Additional conversion equipment was required and four 275-volt sealed-tube ignitron mercury arc rectifiers were purchased. These rectifiers were rated 300 kw continuously, 150 per cent rated load for two hours, and 200 per cent rated load for one minute

The power circuit of these rectifier sets consists of a 2,300-volt 3-phase 60-cycle incoming line through a 50,000-kva interrupting capacity air circuit breaker to a 2,300/261 volt line-to-neutral self-cooled transformer with four taps above and two taps below normal input voltage. The neutrals of the double Y secondary are connected through an interphase winding. A midtap from the interphase winding is carried through a d-c circuit breaker to the trolley feeders. Voltage regulating facilities are provided for proper load division of rectifiers paralleled with motor generators or other conversion equipment.

Air-to-water heat exchangers are used because the air temperature is practically constant and sufficiently low. The coolant circulates in a closed system which includes the ignitrons and temperature regulating equipment. This regulating equipment incorporates a heat exchanger, storage tank, circulating pump, water pressure relay, cooling fan, temperature regulator thermostat, and water overtemperature thermostat.

The rectifier sets are completely automatic. Protection against a-c undervoltage, reversed and open phases, a-c short circuits, arc backs, sustained a-c overloads, misfire, loss of water pressure, water overtemperature, d-c overcurrent, and d-c reverse current are provided. The entire rectifier equipment is arranged as complete units on three separate cars for switchgear, power transformer, and rectifier.

A test run on the first set put in operation served a dual purpose. It presented an excellent opportunity for the personnel responsible for the operation and maintenance of the conversion equipment to become familiar with it and at the same time proper operation was assured when the rectifier was put in operation.

Before the second rectifier could be put in operation it was necessary to change all the generators at this mine so as to make the trolley connection negative and the ground connection positive to conform with the rectifier.

These portable rectifiers are installed in fireproof rooms usually of concrete block construction. Air filters are installed on the air intake end of the room and an air regulator is placed in the air outlet. Level rails are the only foundation requirement. The coal seam height of approximately five feet is sufficient to install the rectifier equipment without resorting to rock removal.

Rectifiers are supplied through a 5,000-volt steel armored cable to a gang-operated disconnect switch located in the rectifier room. A disconnect switch is also used in the feeder from the rectifier to the trolley wire. This arrangement permits isolation of the entire rectifier for inspection and maintenance.

MAINTENANCE

Considerable tube trouble was experienced with the first three rectifiers during the first month of operation. The trouble was traced to gassy tubes as a result of leaks at the points where the glass portions of tube were sealed to the metal tube enclosure. The failure of this seal resulted from inability to obtain the proper alloy steel at the time of manufacture, as a result of wartime restrictions.

Faulty tubes as a rule are detected easily. The misfire relay indicates when one or more tubes are not conducting by tripping and locking out the a-c circuit breaker. Occasional circuit breaker outages due to arc-backs occur without any apparent effect on tube operation. Usually after three consecutive arc-backs the faulty tube will fail to conduct and is found easily. Only one prolonged case of arc-backs has been encountered. To date, no trouble has developed in the firing circuits.

All rectifiers operate unattended, and operation is continuous except on week ends or holidays, when the set may be shut down if not required for pumping on other off shift loads.

Maintenance consists of keeping cooling water at proper levels, periodically lubricating the fan and pump motors, and keeping the sets clean. Daily inspections are made by the sectional repairman and weekly inspections are made by the maintenance foreman. The maintenance requirements of these rectifiers were so negligible in comparison with other equipment that there was a tendency at first to neglect the lubrication of the fan and pump motors.

None of the rectifiers in service has been subjected to continuous full load, but peak loads approaching 200 per cent rated load are observed frequently. The fact that the peak loads are usually of short duration and the additional protection against overload provided by the water overtemperature relay and the a-c overload relays permits a high d-c circuit breaker overload trip setting which keeps circuit breaker outages to a minimum. The ability to carry momentary peak loads makes the rectifier particularly suitable for mining service.

No difficulties have been encountered in operating the rectifiers in parallel with motor generators. In addition to satisfactory operation and ease of installation, the rectifier has high efficiency, freedom from high starting current, and freedom from commutation trouble. These factors contribute toward great economy in operation.

Relay Protection of Transformers

AN AIEE COMMITTEE REPORT

To develop certain criteria of adequate protection, discover inherent limitations, and to recommend desirable devices and methods for protection of power transformers, the AIEE relay subcommittee conducted a survey of over 56,000,000 kva of power transformers. The final report is the result of almost three years of investigation by the working group.

FOURTEEN years ago, the relay subcommittee of the AIEE published a review of practices and trends in the protection of electric equipment, including transformers. During the intervening years, interesting developments have taken place in the devices available for the protection of transformers. However, developments in the transformers themselves and in methods of operation employed to make maximum economic use of equipment have brought about more stringent requirements for protective relays and devices. Improved reliability of power transformers has been utilized in system designs which depend on that reliability to achieve better electrical service with lower investment cost and relaying systems must not impair this reliability. The advances in the art of relays and devices have involved many disturbing compromises between the basic requirements of *service protection* and *limitation of equipment damage* because of magnetizing inrush current, and transformer ratio taps which limit the sensitivity of differential protection. These limitations have become felt increasingly as the art of system protection has progressed and the standards of service have been raised. The increased magnetizing currents associated with the more general use of higher permeability irons and the trend toward higher concentrations of system short-circuit capacity are also factors.

In October of 1944, Chairman W. A. Lewis of the relay subcommittee of the AIEE protective devices committee appointed a working group to study and correlate transformer protection. This group has reviewed the characteristics of devices now available for the protection of transformers, seeking evidence as to their adequacy, for the purpose of crystallizing information on what elements are in greatest need of improvement. A questionnaire was circulated to certain representative users of transformers in the United States and Canada, to determine both present and preferred practices. A total of 28 comprehensive replies have been received, covering experience with over 56,000,000 kva of power transformers. The basis of the final report includes information developed through national meeting conference sessions, and also certain data which were not available for a preliminary report, such as information on the co-ordination of thermal relay characteristics with short circuit protection.

Figure 1 illustrates the various types of protection now being employed for different sizes of power transformers. It is interesting that differential relaying continues to be the most generally accepted protection for transformers, over a broad range of size. However, a keen interest has been shown by a few companies in certain other forms of protection, such as pressure protection, thermal protection, and gas accumulator detection, and increasing use of these is anticipated.

The 28 companies reported 44 explosions or fires in the past five years. At least some of these transformers were protected by differential relays. Several cases were reported where partial winding faults were not cleared by the differential relays.

DIFFERENTIAL PROTECTION

The majority of differential relay installations protect a zone which includes the transformer high-voltage and low-voltage circuit breakers. Probably because of the increased reliability of power transformers, there is an increasing tendency to omit the transformer high-voltage circuit breaker, securing differential protection by totalizing the currents in the high-voltage line circuit breakers, and tripping these (as well as the low-voltage circuit breakers) in case of transformer fault. Thirteen of the reporting companies employ differential relaying with no local high-voltage oil circuit breakers, with bushing current transformers in the power transformer to supply differential relays, and the remote circuit breakers are tripped, either through a pilot wire

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Essentially full text of paper **47-149**, "Relay Protection of Power Transformers," presented at the AIEE summer general meeting, Montreal, Quebec, Canada, June 9–13, 1947, and scheduled for publication in AIEE *TRANSACTIONS*, volume 66, 1947.

This report was prepared by a working group of the relay subcommittee, AIEE committee on protective devices, consisting of **W. R. Brownlee** (M '38) *sponsor*, Commonwealth and Southern Corporation, Jackson, Mich.; **C. E. Asbury** (A '39) Commonwealth and Southern Corporation, Jackson, Mich.; **E. T. B. Gross** (M '40) professor of electrical engineering, Illinois Institute of Technology, Chicago; **E. L. Harder** (M '41) central station engineer, Westinghouse Electric Corporation, East Pittsburgh, Pa.; **L. F. Kennedy** (M '39) relay application engineer, General Electric Company, Schenectady, N. Y.; **W. A. Lewis** (F '45) dean of graduate school, Illinois Institute of Technology, Chicago; **W. E. Marter** (A '40) assistant relay protection engineer, Duquesne Light Company, Pittsburgh, Pa.; **E. G. Ratz** (M '43) meters and relays division engineer, Canadian Westinghouse Company, Ltd., Hamilton, Ontario, Canada; **J. J. Tesar** (M '45) assistant electrical engineer, Cleveland Electric Illuminating Company, Cleveland, Ohio; and **F. J. Vogel** (M '41) research professor of electrical engineering, Illinois Institute of Technology, Chicago system or a carrier current transfer tripping scheme. Eight of the companies reported the use of a similar arrangement, except that local differential relays are used to close a single-pole high-voltage grounding switch to cause opening of the remote high-voltage-circuit breakers.

The relative sensitivity of differential protection may be expressed in per cent as the ratio of the pickup current of the relays to the full load current of the transformer bank. The reported sensitivity ranges from 30 to 200 per cent, the average "typical" value being about 70 per cent.

Certain installations of a generator and a transformer operating as a unit are reported with pickup currents as low as 11 per cent. Most of the companies reported relay speeds of about 0.1 second, although a few reported one-third to one-half second.

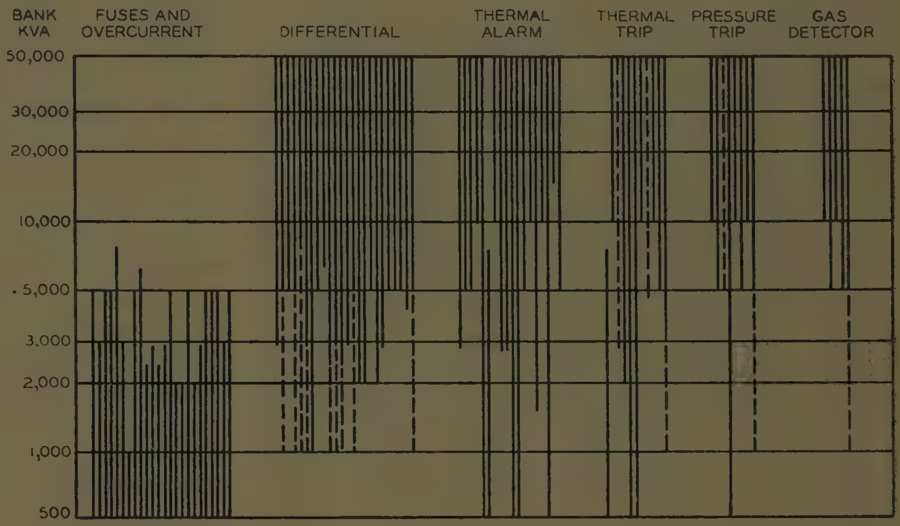

Figure 1. Relay protection applications for various sizes of transformer banks

Each line represents one reporting company
Dotted lines represent tap changers only

Limitations on Through Faults. It is indicated that the limitations in settings of differential relays brought about by through short circuits has been overcome largely, first by the use of ratio-type differential relays, and especially by careful application of bushing current transformers and ratios for better performance.

Limitations of Magnetizing Inrush Current. About three fourths of the companies reported substantial difficulties with false tripping of differential relays on magnetizing inrush current. Some of those that reported no difficulties used relatively long relaying time (one-third to one-half second) and decreased sensitivity, or decreased sensitivity alone. Other things being equal, the magnitude and duration of magnetizing inrush current has been shown to be influenced by: the ratio of the normal flux density to the saturation or maximum flux density of the iron, the value and sign of the residual magnetism, the total impedance of the circuit through which the current flows, and the point of the voltage wave at the moment of closing of the circuit.

For any particular transformer, one important criterion of interference with sensitivity, other things being equal, may be taken as a function of the maximum short circuit kilovolt-amperes at the bus from which the transformer is energized, divided by the kilovolt-amperes rating of the transformer. It has been shown that the maximum inrush current (in per cent of rating) where this ratio is 50, is three times as great as the current associated with a ratio of ten. It is significant that in the most troublesome examples cited, the ratio of system short circuit kilovolt-amperes to transformer bank capacity ranged from 15 to over 150, with a typical value of 70. The continued increase in the interrupting capacities of available circuit breakers and the resulting permissible greater concentration of system capacity indicate the growing importance of the afore-mentioned factor.

The magnetizing inrush current problem is increased by the use of oriented iron with its higher normal flux densities and greater retentivity. The replies make little mention of the use of these units in the larger sizes. However, the design flux densities now permissible with modern low-loss silicon iron are substantially above those flux densities which were in common use 15 years ago.

Remedies for Magnetizing Inrush. One "solution" to the inrush current problem is equivalent to ignoring it. That is, if the differential relays operate when the transformer bank is energized, the bank can be energized again, with the hope that the circuit breaker will remain closed. Some feel that faults are more likely to occur when a bank is energized than at other times and therefore that this procedure is unsatisfactory. Also, the operating practices of many companies require leaving a transformer out of service until tested when differential relays have operated, so as to minimize the possibility of serious explosions and fires when a defective transformer is re-energized.

Many replies indicated that increased pickup of the differential relays had been used. Considerable judgment must be exercised in such instances, since any increase in pickup will reduce, at least proportionally, the sensitivity for which differential protection has been provided. A few companies reported the use of longer time settings.

Three companies reported the use of magnetizing inrush current "suppressors" which decrease the sensitivity for an adjustable time after a bank is energized, unless the voltage drops below a set value. Two other companies reported the use of harmonic restraint relays, and still two others expressed plans for using either suppressors or harmonic restraint methods in the future.

One company has developed a special relay which rectifies the offset current waves to desensitize the differential relays on inrush current. Another device depends for its discrimination on the fact that the magnetizing inrush current is, in effect, a half frequency wave.

A number of companies use residual relays wherever an ungrounded winding of a transformer is connected to a grounded neutral system, and some report the additional use of differentially connected residual relays for the protection of grounded Y transformer windings. Another expedient which has been used to combat the magnetizing inrush problem is the provision of two current transformers per single-phase high-voltage winding for differential protection, similar to generator type, along with an over-all scheme of reduced sensitivity to clear faults outside of this zone. Increased sensitivity is gained in this case for ground faults only, as turn to turn faults produce no unbalance.

The number and variety of methods used to meet the magnetizing inrush situation, without serious interference with the desired relay sensitivity, is an indication that this difficulty is quite general. There is need for improvement in differential schemes to provide increased sensitivity without incurring unnecessary tripping on energizing currents.

FUSE PROTECTION

Many companies are using high-voltage fuses with low-voltage circuit breakers for protection against transformer faults. This choice is an economic one, because in the smaller size of transformers, the cost of a high-voltage circuit breaker may be a substantial portion of that of the transformer. Improvements in high-voltage fuses and the increase in reliability of power transformers have influenced the trend away from providing high-voltage oil circuit breakers for the smaller transformers. Application of fuses to the high-voltage side of transformer banks requires careful analysis, since the fuse is a single pole device and individual phases can be cleared. Under certain conditions, it is possible for a phase-to-phase fault, after blowing one high-voltage fuse, to be maintained through the load connected to the secondary winding of the bank. The impedance of the load may reduce the fault current to a value below the blowing point of the remaining fuses and the fault continues with no protection to clear it, resulting in burned out transformer windings. Another condition which may cause difficulty is the separate fusing on the high-voltage side of two banks which normally operate paralleled on both the high- and low-voltage sides. A fault occurring on the high-voltage side of one bank blows the fuses on that bank only. The fault is again maintained and the application should be checked to see that either the low-voltage bank circuit breaker will trip or that the fuses on the second bank will clear the fault.

In most power transformer applications, the high-voltage fuses are needed to protect only those faults occurring in the transformer, or on the connections between the transformer and the low-voltage circuit breaker. The increased size of fuses on distribution systems and resultant longer relay settings for distribution feeders sometimes give rise to a selectivity problem between the transformer fuses and the reclosing distribution breakers.

More information on fuse operating characteristics as influenced by successive heating and cooling during typical reclosing cycles would be helpful.

THERMAL PROTECTION

Much progress has been made in studies of transformer loading involving hot spot temperatures as a function of time, both with no appreciable loss in transformer life, and with small emergency losses. In order to make the most economic use of transformer capability, a method has been described for loading transformers by copper temperature, using a bimetal element in the top of the transformer, heated from a current transformer. An ambient compensated time lag device has been offered for the purpose of duplicating the temperature-time capability of the transformer.

A number of companies reported the use of embedded temperature detectors. Recent transformer designs have avoided the use of such devices in the higher voltages, because of the difficulty of securing the desired high impulse level.

Most of the companies that replied used the ordinary top-oil-type thermometers, which are agreed to be at best an approximation. About half of the companies make extensive use of hot spot temperature devices for sounding alarms, and some are making increasing use of thermal relays for disconnecting transformers, even at attended stations. Two companies reported several cases of faulty co-ordination between thermal-type devices and feeder overcurrent relays, because transformers have been disconnected incorrectly (and locked-out) during nearby short circuits. Investigation disclosed that some of these thermal devices had been designed to overprotect the transformer in the fault current range, and hence would operate more quickly than the normal feeder protection. Fortunately, the shape of the time-current characteristics can be controlled by design within quite wide limits.

SHORT TIME CHARACTERISTIC

Co-ordination with overcurrent relay protection requires a rather substantial delay in operation of transformer thermal relays on short circuit currents. Many distribution feeder circuits cannot employ instantaneous tripping devices because of the presence of nearby transformer banks with large fuses, and these feeder circuit breakers usually are set to reclose automatically for a total of four tripping operations. Also, in many instances, the transformer has a low-voltage circuit breaker between its terminals and the bus from which feeders are supplied, in which case complete co-ordination is required between the feeder circuit breakers, the transformer circuit breaker, and the transformer thermal relay, with ample margin for repeated operations, different initial top-oil temperatures, and other related factors.

Therefore, it is recommended that the short time characteristic of the transformer thermal devices be such that they will withstand, without operating, fault currents of at least 20 times the rated load current for a minimum of 5 seconds, and 5 times the rated load current for a minimum of 40 seconds. Below 5 times rated load the curve may blend into the thermal protective characteristic desired for the power transformer. These currents are assumed to be applied following full-load operation and are based on the self-cooling rating of the transformer.

PRESSURE PROTECTION

Considerable attention has been focused recently on the use of pressure relays to provide sensitive supplementary protection for power transformers. A simple type of device consists principally of a bellows, adjustable to operate when the tank pressure exceeds 5–15 pounds per square inch (depending on the relative position of the device on the transformer case). Another device, which has a diaphragm with a small hole sufficient to permit gradual changes in pressure to be equalized without operation, is designed to operate on sudden changes in pressure. This element usually is furnished as part of a combination gas-pressure and gas-accumulator device. A third type of device consists of a combination unit mounted directly in the piping connection from the transformer to the conservator, the "pressure element" consisting of a float or vane which is pushed aside by a rush of oil through the connecting pipe.

The float or vane type of pressure device has found extensive applications in continental Europe and Great Britain as the principal protection for power transformers. A few of the perforated diaphragm units have been used in the United States, although each company has installed only a small number of experimental units, and therefore little experience data are available. However, four of the larger users of transformers in Canada have made extensive applications of a perforated diaphragm type of unit and report very satisfactory results. Theory and limited available experience indicate that this pressure device may provide more sensitive protection than that usually obtained with differential relays.

BELLOWS-TYPE RELAY

More recent installations in the United States have been of the bellows type of relay. The operating speed is about one cycle at pressures 15 per cent or more above the setting. Five companies reported using these on power transformers for increased sensitivity, three reported their use for alarm only, and two reported success with application to induction regulators which have no other *equipment* protection; that is, the regulator is protected as part of distribution circuit. Successful installations are reported, even in the case of nonoiltight indoor units, where the pressure wave has been sufficient to trip and lock out the circuit, thereby preventing explosions which might have occurred when the circuit was re-energized. Also, destructive failures have occurred where, in the opinion of those reporting them, the use of pressure relays might have minimized damage to the transformers.

Some of these failures were preceded by several observed voltage surges or recorded ground currents of very short duration, which indicated preliminary faults that extinguished themselves before operating the differential relays.

The working group feels that the use of pressure protection for power transformers offers much promise as supplementary protection with differential relays, for protection of smaller transformers together with overcurrent protection, and for difficult applications such as with regulating transformers, feeder voltage regulators, rectifier transformers, and other special types of transformers.

GAS DEVICES

For many years the Buchholz type (*EE, June '47, pp 564–9*) of gas accumulator fault detection (combined with pressure protection) has found widespread use in continental Europe and in Great Britain. Probably the rather extravagant claims made for this device, as the sole protection for transformers, and the former royalty costs which were considered excessive have been important factors in retarding applications in the United States. The device consists essentially of two float chambers connected in the piping from the transformer to the conservator so that any evolved gas will be trapped in the system. One float chamber collects gas bubbles given off gradually, and operates to sound an alarm. The float or vane in the other chamber is operated by a rush of oil through the piping to close a set of contacts which disconnect the transformer. Many examples have been cited of either core faults or partial winding faults which were detected by the gas accumulator system and severe damage thus prevented.

In Canada and in the United States, the diaphragm and float combination device has had moderate application. This device is designed for mounting directly on the transformer case, and contains a float chamber to sound an alarm on the accumulation of gases. Favorable experience is reported by four of the larger users of transformers in Canada, who have made extensive applications of the diaphragm-float combination relay. One reported the detection of several high resistance joints out of 40 transformers in ten years. Another cited detection of a number of failures of core bolt insulation, and a third reported discovery of seven cases of defective brazed joints out of 36 transformers in a period of slightly more than three years. All of these were detected and repairs made before the faults progressed beyond the incipient stage.

OBJECTIONS

Those who prefer not to use gas accumulator relays usually cite as objections: that special transformer construction may be required, that it is discouragingly expensive to untank and inspect a transformer after a relay indication, but before the fault has developed sufficiently that it can be found, and that it is difficult to maintain the devices and to interpret their indications. No special transformer construction was used in any of the reported Canadian installations, and methods used to interpret indications have been quite successful. Accumulated gas is tested for combustibility, and sometimes a chemical analysis is made. The color of the gas provides a quick indication. Considerable weight is given to the length of time between alarms, especially if the interval is decreasing. A Canadian manufacturer reported tests on a joint of 40 interlaced strands, one of which intentionally was made defective. Current was passed through the joint to complete failure, which occurred 12 weeks after the first gas alarm.

Available gas accumulator relays now are limited in application to conservator-type transformers. An electrochemical device is available to detect incipient faults in askarel-insulated transformers. Experimental installations have been made in Canada of a platinum wire type of device to detect combustible gases in small oil-insulated sealed-tank transformers.

It is felt that the value of gas accumulator relays for detecting incipient faults has been underestimated generally in the United States, and that with proper application and interpretation, their use with conservator-type transformers may be worthy of more consideration. It is hoped that adequate methods will be developed for applying the gas detection principle to other types of transformers.

CONCLUSIONS AND RECOMMENDATIONS

Differential protection is the generally accepted method of clearing transformer faults. This provides satisfactory speed of clearing, usually covers the entire zone between circuit breakers, and offers a fair degree of sensitivity.

1. Incorrect tripping on magnetizing inrush current is a major problem, especially where the available short circuit kilovolt-amperes on the bus to which the transformer is connected is large with respect to the transformer size. Trends toward higher design flux densities accentuate the problem.

2. The use of either transferred tripping, or a local line grounding switch to trip a remote circuit breaker offers attractive possibilities for providing differential protection to transformers without requiring separate high-voltage circuit breakers.

3. There is need for improvement in differential schemes to provide increased sensitivity without incurring unnecessary tripping on energizing currents.

Combinations of high-voltage fuses and low-voltage circuit breakers provide a reasonable compromise type of protection for the smaller sizes of power transformers. Problems of selectivity between these fuses and reclosing circuit breakers on feeders supplied from the transformer are complicated by the various reclosing cycles used. More information on the various heating and cooling time constants of different types of fuses would be helpful in developing better methods of predetermining fuse and circuit breaker co-ordination.

The wider application of pressure protection offers considerable promise

1. To provide supplemental protection with sensitivity greater than that usually obtained with conventional differential schemes alone.

2. For protection, when used with overcurrent relays, where it is not feasible to provide a satisfactory differential scheme.

3. To solve inherently difficult application problems, such as with step regulators and rectifier transformers.

4. For fast low-cost protection and reclosing lockout of feeder voltage regulators.

The value of gas accumulator relays for detecting incipient faults has been underestimated generally in the United States.

1. Substantial experience in Canada has demonstrated the value of gas accumulator relays to detect conditions such as turn-to-turn faults, core insulation failures, and defective joints.

2. Objections commonly raised to the gas accumulator method of detecting faults can be overcome largely by suitable application and proper interpretation of relay indications.

3. The present commercially developed gas detector relays are limited in application to conservator-type transformers. Experimental installations indicate that devices may be developed for extending gas detection principles to other types of transformers.

Liquid Cooling of Turboalternators

C. J. FECHHEIMER
FELLOW AIEE

It is at least as large a step from hydrogen to liquid cooling as it was from air to hydrogen cooling of large turboalternators. A method of construction for liquid-cooled machines is difficult but the advantages to be gained by it are many and include improved temperature conditions, elimination of corona, and winding for higher voltages.

FORESIGHT of a number of engineers, a little less than a quarter of a century ago, led to the successful development of hydrogen-cooled turbine generators. Until some 15 years ago many operating and manufacturing engineers were skeptical about the safety of hydrogen as a cooling medium. Today those fears are dispelled and practically every large turbine generator built recently in the United States is hydrogen-cooled.

By contrast, the writer ventures to say present day engineers look askance at the idea of liquid cooling, especially for the rotors of turbine generators. It is feared that the liquid cannot be made to pass into, through, and out of a high-speed rotor without giving trouble.

From the standpoint of gains to be achieved, provided the mechanical difficulties can be overcome, it is at least as large a step from hydrogen to liquid cooling as it was from air to hydrogen cooling.

It is recognized that, aside from magnetic saturation and mechanical stresses, the temperature rise of the rotor winding imposes the limitation as to the over-all dimensions when the load current lags behind the voltage. For, to decrease the D^2L (where D is the rotor diameter and L is the rotor length) it is necessary to increase the ampere turns, and that gives rise to increased copper loss. Thus, one principal gain to be affected by liquid cooling of the rotor is that the copper loss can be increased for a given temperature rise, and the machine can be made smaller, lighter, and cheaper for a given rating.

A second important gain is that the rotor copper temperature will be nearly uniform, both radially and longitudinally, and consequently there should be no damage or deformation due to differential expansion and contractions, as in gas-cooled rotors.

A minor advantage is that the temperature of the copper and the steel above that of the entering liquid can be predicted within only a small percentage of error, if the losses and the various constants of the materials are known. With gas cooling, the highly turbulent flow in some places, the consequent uncertain heat transfer rates, and the complex heat flow, defy calculation.

For a given internal stator diameter (determined by the previously chosen rotor external diameter), and for given magnetic densities and voltage, the stator external diameter can be made smaller than for gas cooling.

Other advantages of liquid cooling are: stator copper temperature is nearly uniform; there is absolutely no corona; the stator may be wound for considerably higher voltage than is practical with gas cooling; the rate of flow of the liquid can be regulated readily, and thereby the temperature rise of the stator winding can be controlled to a large extent; and the internal reactances are higher than with gas-cooled machines, thereby admitting of smaller external reactors, or possibly their omission.

ROTOR CONSTRUCTION

The same liquid is used repeatedly in a closed circuit system. In the external part of the circuit, not shown in the illustrations, the liquid is cooled in some established heat exchanger, and in series therewith is a pump and some device for removing entrapped air (or other gas). The latter is needed when the machine is started, and probably may be by-passed when the machine has attained full speed. The front end is shown at the right and the turbine end at the left in Figure 1. Figure 2 shows the end elevation.

Figure 1 shows the stationary metal tube A-B, which clears the bore in the shaft, welded to the plate C, which in turn is bolted to a rigid stationary plate D. The liquid flows from A to B and is discharged near B into the pocket E. It then passes through the radial holes F and G, into the casing H, then flows radially outward and then into axial ducts J and K. These ducts, J and K are the main cooling ducts and extend the full axial length of the rotor body. The liquid then flows radially inward to H', through radial holes G' and F', then axially through the hole L in the shaft, to the discharge radial holes M. It then collects in the annular space, N, and later it passes through the external pump and heat exchanger in the external part of the circuit, back to the entrance tube A-B.

During the passage of the liquid through the rotor body, the centrifugal action thereon at the incoming end (H to J and K) is balanced substantially by the centrifugal action at the leaving end (J and K to H'). However, the head generated in the centrifugal pump at M is not balanced at the other end. This head generated

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Essential substance of paper 47-95, "Liquid Cooling of A-C Turbine Generators," presented at the AIEE winter meeting, New York, N. Y., January 27-31, 1947, and scheduled for publication in AIEE *TRANSACTIONS*, volume 66, 1947.

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from the shaft bore to the shaft external periphery is considerably more than is needed to overcome the sum of the hydraulic resistances opposed to the flow of the coolant from the entrance at *E* to the discharge in *L*.

The large centrifugal action between the shaft bore and the rotor ducts will cause entrapped gases to collect in the pocket *E* at the incoming end. The gases then are drained off through the small stationary tube *P* and can be allowed to issue through a suitable trap. To insure that the gases escape, the pressure at *E* should be slightly above atmospheric but should not be so high as to cause the liquid to flow out between the shaft bore and the external periphery of the tube *A-B*. The pocket *E* is enlarged so that centrifugal action will cause the liquid to flow into the radial holes *F* and *G* and not into the annular space between the shaft bore and the tube *A-B* even with the pressure in *E* slightly above that of the atmosphere.

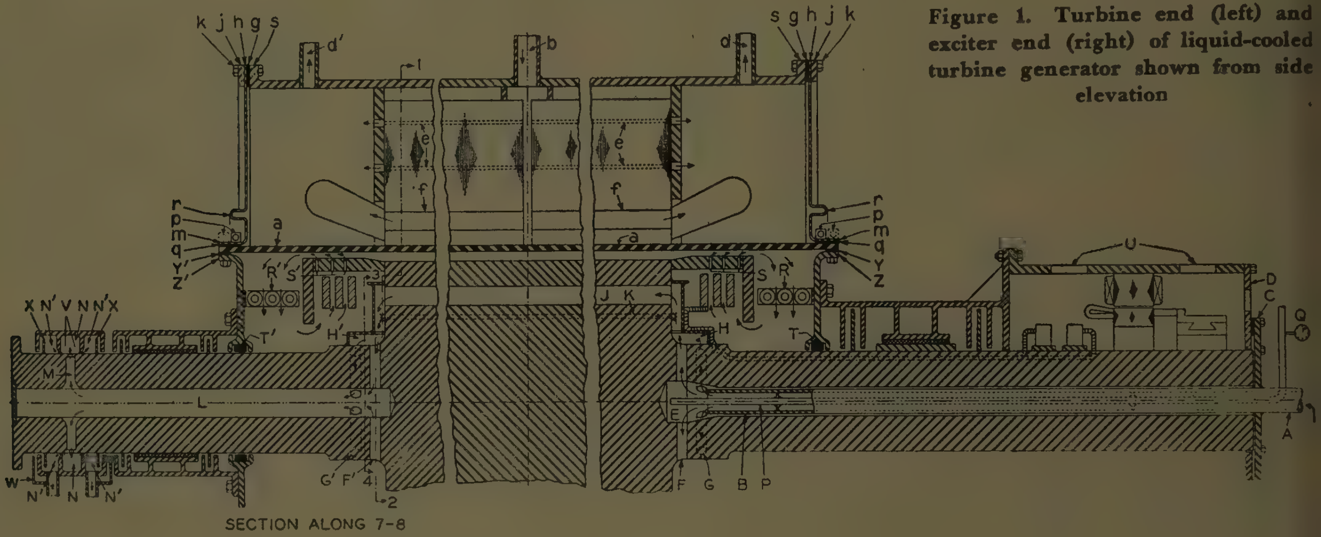


Figure 1. Turbine end (left) and exciter end (right) of liquid-cooled turbine generator shown from side elevation

There is appreciable resistance to the flow of the liquid through the rotor ducts, and the resultant loss of head is sufficient to reduce the pressure in the shaft bore at the turbine end to a value below atmospheric; but with suitable proportions the pressure there should be appreciably above a vacuum. Thus, a reasonable loss of head through the rotor ducts is of the order of 20 feet or less, and with 34 feet of water as atmospheric pressure, added to the positive head at *E*, there is still ample pressure above vacuum.

If the shaft diameter is determined by a usual value of working stress in torsion for the transmitted load, for a large generator at either 3,600 or 1,800 rpm, the head generated by centrifugal action at *M* is several times the equivalent of sea level atmospheric pressure. Consequently, there would be danger of cavitation in the shaft bore at the turbine end if there were no provision for absorbing the additional head. This is secured by restricting the discharge ducts near the shaft periphery, as shown by means of orifices. To insure against cavitation at the entrance of the radial ducts *M*, the velocity of the liquid is made low by making the entrance section relatively large and then curving, so as gradually to accelerate the liquid. The curved portion terminates in a cylinder which continues to the orifice near the external diameter of the shaft.

After the liquid is discharged from *M*, it enters the annular space *N* at high velocity. This space fills rapidly and the liquid whirls and most of its kinetic energy is dissipated as heat. The calculated mean temperature rise of the liquid due to this loss usually will be less than one degree centigrade. This means also that the power required to drive the centrifugal pump *M* is small and decreases the generator efficiency by an extremely small amount.

The liquid next passes through the restricted areas *V* between the two annular spaces *N* and *N'*, and finally is discharged from the bottom of *N'* into suitable pipes, whence it flows into the heat exchanger and external pump, and is returned to the entrance tube at *A*. The whirling rings *X* should prevent the axial escapement of liquid while the rotor is running at normal speed. When the machine is being prepared to run at or is near standstill, there may be a small escapement of liquid. Practically all of this may be caught in the gutters *W* and returned to the main part, the very small amount that might still leak out during the starting period may be caught and drained. There also may be a little leakage near the entrance at *C* although this can be eliminated substantially by suitable gaskets or caught in gutters and returned. It will be noted that at standstill, or very low speed, the flow is produced by a low-pressure external pump. Consequently, the volume of flow is less than when running at normal speed, and the leakage is very small. Although the volume of flow is less at very low than at normal speed, the temperature rise of the copper (above the ingoing coolant) for a given copper loss should be nearly the same, since the duct surface drop and temperature rise of the coolant are small.

THE DUCTS

The ducts in the rotor body, J and K, are shown rectangular in section. Other suitable sections, as trapezoidal, may be chosen. They are machined (by milling or planing) from the external cylindrical surface and the outer parts of the J ducts are filled subsequently by steel pieces, suitably welded in place. The small ducts, K, below the winding slots are cut in after the main winding slots are machined, and their outer parts are covered with thin plates welded in place at the bottom of the main slots. One of the larger ducts is in each of the rotor teeth, and in the central pole adjacent to the last slots. A small duct is located below each rotor slot. If the rotor is built of plates, circular holes can be drilled, and to prevent leakage of the liquid at the junctions of plates, thin walled metal tubes can be pushed into the ducts, and these tubes can be welded at the ends of the rotor body.

One way of constructing the casings H and H' is shown in Figure 1 and 2. They are fabricated entirely of steel sheets of such thickness that the stresses therein due to liquid pressure and their own centrifugal forces will be of the usual order for safety.

In order to absorb the heat generated in the coil ends of the rotor windings, the gas at the ends is caused to circulate by centrifugal action, passing through holes, S, in the retaining rings, and passing over the surfaces of circularly bent tubes and between fins on the tubes R and R', in a continuous closed circuit. These finned tubes are stationary and are supported, as indicated. Water or other liquid is circulated within these coils to absorb the heat. The finned tubes may be placed in some other location in the gas stream.

In order to reduce the windage loss, to improve the heat conductivity of the insulating wall in the rotor slots, and to improve the heat transfer between rotor coil ends and the circulating gas, and between the gas and the finned tubes R and R', the rotor is operated preferably in a hydrogen atmosphere. Safe operation is assured by extensive experience, during the past 15 years, with hydrogen-cooled turbine generators. The gland seals for minimizing the escape of hydrogen and infiltration of air are indicated at T and T'.

With this construction, calculations of the heating of the rotor coil ends in one atmosphere of hydrogen, when blocking is provided to insure high gas velocities adjacent to the coil surfaces, indicate that, when running, those parts will have about the same order of temperature rise as the copper in the embedded parts.

Fitting snugly in the stator bore is a cylinder, a, of insulating material. The flanged disks Z and Z' are bolted to this cylinder, being separated therefrom by suitable gaskets, Y and Y'. Thus, a, Y, Z and T, (and a, Y', Z' and T') form the inner sides of the structure wherein the hydrogen gas is retained.

In Figure 1 a suggestion is given as to how the rotor leads may be brought out from the winding to the collector rings. A direct connected exciter also is shown. It is important that all welds be leakless, and that they be tested with great care.

STATOR CONSTRUCTION

The liquid-cooled stator is illustrated in Figures 1 and 2. The coolant is an insulating liquid, either transformer oil or some noninflammable liquid which is circulated in a closed system, with an external pump and a suitable heat exchanger in series, the latter two being omitted in the illustrations. As shown, the liquid enters at the middle, at b, and is discharged at both ends, at d and d'. For some ratings, the liquid may enter at one end and be discharged at the other end. (Evidently there are advantages and disadvantages to axial flow in both directions, as compared with axial flow in only one direction. Also, with a middle duct, the direction of flow could be reversed.)

Axial ducts are provided in the laminations, at e and f in Figures 1 and 2, the proportions of which can be calculated by the designer. Such proportions are predetermined from the magnitude and distribution of the losses to be absorbed, from the physical properties of the coolant and from the assumed temperature rises.

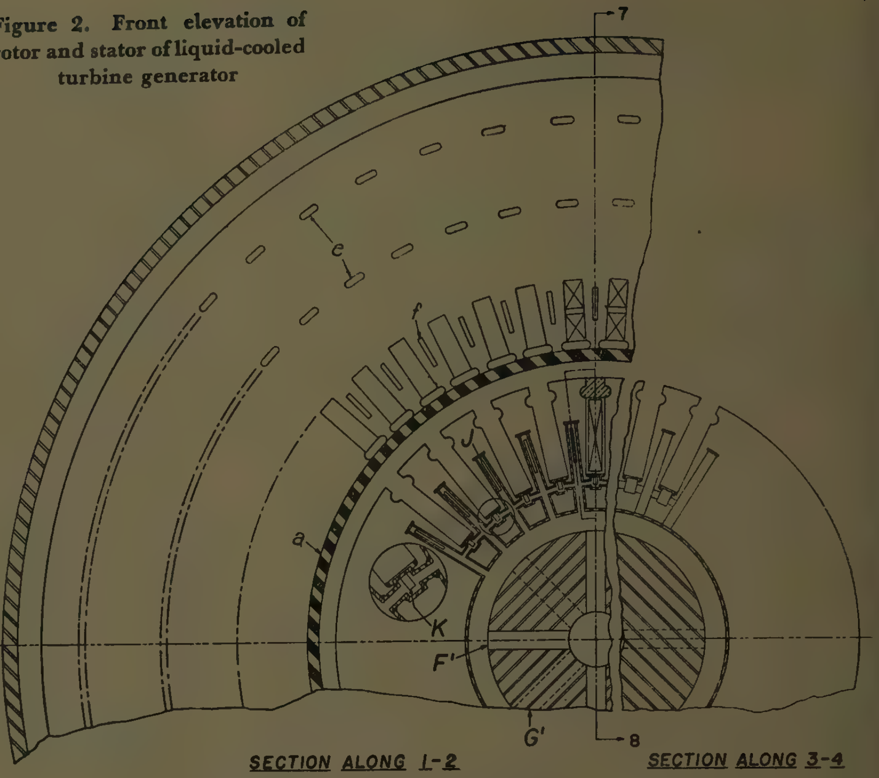
The insulating walls of the stator coils can be made of materials like those used for transformer coils for the same voltage. As the insulating coolant permeates the solid insulation, the volts per mil of thickness can be taken to be that established by good transformer design. The wall thickness is then less than with air or hydrogen as the cooling medium. The thermal conductivity is improved over that in the air, and should be at least as good as in hydrogen. Furthermore, the liquid coolant reduces the lamination temperature below that obtainable with hydrogen. Because a duct is in each tooth the coolant is close to the coil, and the thermal drop in the steel teeth (in the favorable planes of the laminations) is not large. Consequently, the permissible thermal drop through the insulating wall may be higher than for hydrogen.

Owing to the much better thermal properties of the coolant (giving greatly improved heat absorption and heat transfer), the ducts (e and f) may be of such reduced proportions that the space occupied by them is very small as compared with the space for the ducts in a hydrogen-cooled machine.

The ducts f, in the teeth, do not add to the external diameter. This fact, plus shallower slots, plus much less space for the ducts in the core, permit of a smaller external diameter of the stator laminations for given internal diameter, magnetic densities, and stator voltage.

The stator is closed at each end by the diaphragm, h, which is separated from the frame flanges by means of a fluidtight oil resisting gasket, *g*. The rings, *j*, are interposed between the heads of the bolts, *k*, and the outer surfaces of the diaphragms, *h*. The diaphragms may be provided with one or more circular corrugations, *r*, to increase their flexibility and prevent high stresses arising from transient pressure due to a fault. The diaphragms have axial flanges, *m*, whose internal diameter is nearly the same as the bore of the stator laminations, and are separated from the cylinder, *a*, by means of gaskets, *q*. These flanges are pressed hard against the cylinder, *a*, through *q* by means of two clamp rings. The flanges of these two rings are not in the same location circumferentially to insure positive pressure on the gaskets for all peripheral positions, and thereby prevent leakage of oil.

Figure 2. Front elevation of rotor and stator of liquid-cooled turbine generator



An advantage of the high dielectric strength of the stator coolant is that the stator can be wound for higher voltage than is the present practice in the United States. Thus, in some instances, step-up transformers may be eliminated. Furthermore, oil avoids corona formation. The damage arising from corona in air is well known. (Although corona is present with high voltage when hydrogen is the cooling medium, it generally is believed that corona is not damaging under such conditions.)

The designer is sometimes in a quandary with large machines, especially for two poles, as to how to secure a sufficiently small number of stator conductors with the desirable Y connection when the voltage is of the order of 13,800 volts. When the stator voltage is raised, this difficulty is reduced. Also, the switchgear costs may be, and bus copper weights are, reduced by adopting a higher voltage.

HEAT ABSORPTION AND TRANSFER

The thermal gains to be effected by some liquids over air or hydrogen for cooling are enormous. At present, many engineers justifiably are pleased with the gains of hydrogen over air, and especially if the pressure of hydrogen is about twice that of the surrounding air. But such gains are insignificant when contrasted with the benefits to be derived through use of liquids, especially with water. The volume per unit of time, as adopted for machines, with liquids, would be much less than with gases. The velocities also would be lower and the duct sections and surfaces smaller, but even so, with entirely practical values, the temperature rise of the coolant (associated with heat absorption), and the thermal drop from the duct surface to the coolant (associated with heat transfer) are much smaller than with gases.

Oils are inferior to water as coolants, but greatly superior to gases. It should be noted that for the stator the velocity (and volume) of the coolant are controlled readily, and the temperatures are measured easily. Thereby the velocities can be raised, if need be, to insure turbulent flow.

It would be desirable to operate the rotor cooling system in parallel with the lubricating system. Unfortunately, the viscosity of the bearing oil considered is such that the flow in the ducts probably would be laminar, and therefore the heat transfer rate would be lower than the values for which turbulent flow was assumed. Other petroleum oils have been given consideration, and it appears that some of them have possibilities. The low flash point, and consequent fire hazard, of kerosene prompted its exclusion, although it is excellent as a coolant.

Ethylene glycol plus an inhibitor is used extensively with water as an antifreeze in automobile cooling systems. For this application it has splendid properties from the thermal standpoint. It is highly hygroscopic. When a suitable inhibitor is added there should be extremely small corrosive action of the steel surfaces. Some special silicones may prove to be suitable for the rotor, and may warrant further investigation.

Without doubt, water is the best liquid coolant for the rotor from the thermal standpoint. The objection that may be raised is that it might cause corrosion or scaling of the steel surfaces. However, assurance has been given by a water-treatment expert chemist that, with a suitable inhibitor, and with the conditions obtaining in this application, such will be practically negligible. These conditions are: only distilled or deionized water with proper inhibitor will be used; it will operate only in a closed system; and the temperature of the liquid will not exceed 70 degrees centigrade in any place in the closed circuit. The Reynolds number with water is so high as to insure desirable turbulent flow in the ducts.

An important point is that with the large drop through the insulation there should be substantially uniform thermal conductivity of the insulating wall in order that this drop will not vary.

ROTOR TEMPERATURE DISTRIBUTION

If the copper is preheated at standstill, or at very low speeds, so that full load copper temperature is attained, and the rotor is brought up to speed, without change in temperature, after which the same, or nearly the same, temperature is maintained, and if the cooling (that is ventilation in gas-cooled rotors), is the same at very low speed as at full speed, and if the copper and steel temperatures are uniform (though different from each other) then there will be no deformation due to expansion or contraction of the copper. (This assumes that the copper is not bound longitudinally by adhesion to the slot sides, which experience indicates is not the case.) Then the copper expands uniformly as a unit for its entire radial depth (while at, or near, standstill), and there are no forces to alter the axial length after normal speed is attained.

These conditions cannot be met in large modern gas-cooled machines, because such machines, as built in the United States, are provided with internal fans, and therefore the ventilation cannot be the same running as at standstill; and the temperature distribution of the copper when running is not found to be uniform either radially or axially.

According to calculations, with water as coolant, the radial differences of copper temperature can be kept to less than five degrees centigrade, and the calculated difference between the steel temperature at standstill and when running is of the order of only two degrees centigrade, assuming excitation for full load in either case. It seems highly probable that there should be no deformation with water as the coolant, with careful proportioning, and with proper preheating, and with soft copper, provided the current in the rotor winding is maintained constant when it is running.

If, after attaining steady state temperature at full load, the load is decreased, one helpful procedure is to keep the rotor current from falling by allowing the reactive kilovolt-amperes to increase, and thereby to decrease on paralleled synchronous machines. This generally can be done only to a limited extent, and another possibility is to decrease the rate of primary water in the heat exchanger so as to increase the temperature of the entering coolant.

With hydrogen for the coolant, with high ratings at 3,600 rpm, and with the great effort that is being made to reduce the D^2L, there may be high local temperatures in the rotor copper, even with hydrogen at two atmospheres. As reported in several papers, particularly in a fairly recent paper published in England,[1] a great amount of trouble was experienced from deformation of the rotor copper, arising primarily from unequal copper temperatures. It is the author's opinion that recent large 2-pole rotors built in the United States with hydrogen cooling are not operated at as high average temperatures as those built in Great Britain for air cooling. However, those in the United States are for 60 cycles, as contrasted with 50 cycles in England, and the recent maximum kilovolt-amperes ratings are at least three times those for machines whose data appear in the English paper. Is it not likely that in those very large American machines there is the possibility of serious deformation, even when wound with hard-drawn copper?

At the present writing there is no intention to state what are the limits of either hydrogen- or liquid-cooled rotors. But it seems evident that dangers from deformation can be eliminated from a liquid-cooled rotor. Also, short-time large changes in rotor current will not cause deformation owing to the storage of heat in the copper. These statements are for soft copper, and limits as to change in rotor current are greatly increased with hard-drawn copper.

Some years ago an experimental and analytical study was made of ventilation of turbine-generator rotors. A report was written, but the findings were not published. It is beyond the scope of this article to go into lengthy explanations of the factors that are productive of inequalities of distribution of gas volumes. It is unfortunate that, while in operation under load, there is no practical means for measuring the rotor copper and steel temperatures at selected points, as on stationary apparatus. It may be possible to obtain an approximate estimate of the gas volumes for each radial vent duct and the volumes in the axial ducts, but the highly turbulent states and resultant uncertain heat transfer rates, together with the complex heat flow, make the calculation of local temperatures almost impossible.

It is interesting that the temperatures produced by the copper loss may be measured at selected points in a liquid-cooled rotor at standstill, with results that are within a small percentage of those at full load.

STARTING PROCEDURE

In a new machine, initially all ducts are filled with air. The insulating liquid coolant for the stator is caused to circulate with the aid of the external pump, there being a suitable vent outside to allow air to escape (later a valve in the vent is closed to prevent escapement of liquid). It is advisable to cause the liquid to enter a vacuum tank, or other deaerating device, before it passes into the stator, so as to exclude the air. Moisture also should be removed, as is the usual practice with transformers. The suggestion is offered to have instruments to indicate the pressure and volume of flow at all times. The coolant should be in the stator long enough to insure that it has penetrated the insulating walls before the machine is started.

Hydrogen should be introduced around the rotor and maintained for a sufficient length of time for it to penetrate the rotor's insulating walls. With the rotor stationary, the rotor coolant should be circulated long enough to insure the expulsion of air everywhere, the initial procedure being similar to that for the stator. If water is the coolant, it should be distilled or deionized and treated with a suitable inhibitor. The volume of liquid per unit of time at standstill will be less than when running. The pressure needed for driving the liquid through the ducts at standstill is not large, and suitable gaskets are provided to eliminate leakage, or reduce it to a very small amount. At the discharge at N' the pressure will have dropped so that the leakage there will be very small. What does leak will be gathered in the gutters, W, and drained into the outlet.

When there is assurance that the rotor liquid is circulating without entrapped gases, the rotor is rotated at very low speed, and then electric current is caused to flow in the windings. The flow of the coolant through the rotor ducts should be maintained. During this preheating operation there should be little or no primary water flowing in the heat exchanger, so that the temperature of the coil ends will not differ greatly from that of the embedded parts. The resistance of the winding should be measured by voltmeter-ammeter method at various times and it is advisable to have a continual check on the resistance when at full speed. The temperatures of the ingoing and outgoing liquid also should be recorded on a chart.

When full load rotor copper temperature is attained, the rotor should be brought up to speed, care being taken to adjust the excitation so as not to generate too high voltage. The generator should be synchronized rapidly and loaded, so that there will not be a large change in rotor temperature. The flow of primary water in the heat exchanger should be started or increased when full speed is approached. As previously pointed out, small temperature changes will not produce plastic deformation of the copper. If future experience so dictates, the deaerators may be by-passed.

NOTES ON SIZE

Attempts have been made to compare the calculated rotor and stator D^2L for 100,000-kva 80-per-cent-power-factor 13,800-volt 3-phase 60-cycle 1,800- and 3,600-rpm liquid-cooled and hydrogen-cooled machines at one and at two atmospheres. For 3,600 rpm the calculated short circuit ratio is 0.83. The D^2L's are around 80 per cent of those for hydrogen-cooled machines for two atmospheres, or about 66 per cent of hydrogen-cooled generators for one atmosphere.

It should be noted that the limitation is not the average rotor copper temperature, but the maximum rotor temperature. With the small differences in copper temperatures, in liquid-cooled machines, higher average temperatures should be permissible, which would mean a further reduction in D^2L. Also, with the better heat transfer in the heat exchanger from water to water than is obtainable from water to hydrogen, the temperature of the coolant entering the rotor should be lower than for hydrogen, thereby giving a larger temperature rise above the primary water for the same maximum temperature. It is difficult to indicate how much further gain can be secured thereby, but it is likely that, after some practical experience will have been obtained, there will be appreciable further reductions in D^2L.

CONSTRUCTION COMPARISON

For a given D^2L there are some added costs, and some reduced costs of liquid-cooled generators contrasted with hydrogen-cooled. Liquid-cooled machine reduced costs result from omission of: internal fans, internal end-bell walls, large internal coolers, multiplicity of vent ducts for stator and rotor, and duct work for flow of coolant to and from internal heat exchanger; also the outer end bell costs are much less because of the considerable reduction in diameter, with the end bells designed to withstand explosion pressure. Added costs result from: machining of ducts in rotor (nearly offset by machining of rotor vent ducts for hydrogen), welding of ducts and casings which must be leak proof, insulating cylinder in stator bore, external heat exchangers for stator and rotor, and internal heat exchangers R and R', and pumps and deaerators for both stator and rotor.

The writer is unable at present to give a comparison in dollars, but he is of the opinion that, for equal D^2L, there will be little difference in first cost. But the smaller D^2L for a liquid-cooled machine should make the cost appreciably lower, nearly in proportion to the D^2L. Of course, the reduction in floor space is important to power companies.

Two models should be constructed and tested in order to check the calculations. One should simulate the rotor's hydraulic circuit and the other the rotor's heat circuit. The hydraulic model would be advisable in order to make certain that the hydraulic system will function properly in a large generator. Expense of constructing and testing such a model would be relatively small for the benefits derived. A hydraulic model is being built at the time of publication of this article.

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The Concentrated-Arc Lamp in a Light Beam Communication System

W. D. BUCKINGHAM C. R. DEIBERT R. V. MORGENSTERN

An experimental light beam telegraph circuit which utilizes a concentrated-arc lamp has been in operation for more than three years over lower New York, N. Y. The 3/4-mile circuit has demonstrated that in fog-free localities dependable high quality communication is possible over light beam systems.

COMMUNICATION possibilities of parts of the electromagnetic spectrum higher in frequency than the shortest radio waves were investigated early in 1939 by The Western Union Telegraph Company. A study of atmospheric transmission characteristics, as well as the energy sources and detectors then available, pointed to the wave length band between 0.3 and 1.5 microns, or millionths of a meter, as the most promising. This band covers the visible spectrum together with the adjacent ultraviolet region down to the transmission limit of ordinary glass and the infrared region out to the long wave threshold of photoelectric detectors.

Signaling by means of a beam of radiation requires modulation of the beam amplitude, frequency, or phase. Tests on the infrared, visible, and ultraviolet light sources available, showed none to be ideally suited for light beam communication purposes. Those which could be modulated at audio frequencies were of low intensity, while stable high-intensity sources, such as tungsten filament lamps, could not be modulated except by valves or shutters outside of the lamps. The ideal source seemed to be one of high intensity, stable position and characteristics, and one capable of being modulated directly without the use of light valves. From the standpoint of economy of energy, and the desirable secrecy characteristics of narrow-beam transmission, a small-size transmitting source was also required. The search for a light source having these specifications led to the discovery of the concentrated-arc lamp.

This lamp employs two fixed, permanent electrodes which are mounted in a glass bulb filled with an inert gas, usually argon. Figure 1 shows that the cathode or negative electrode consists of a tantalum tube packed with zirconium oxide. The positive electrode or anode is a molybdenum plate with a hole in the center which provides a window for the emergence of the light that radiates from the cathode. During manufacture, the exposed oxide surface at the end of the cathode is reduced to metallic zirconium. When the lamp is operating, this extremely thin layer of zirconium metal is melted and maintained as an incandescent pool by the intense argon ion bombardment of the arc. The majority of the visible radiation of the lamp is emitted from this incandescent surface. This radiation has a continuous spectral distribution of the black- or gray-body type which reaches its maximum value near one micron and extends from at least 0.3 to 5 microns, which are the limits of the spectral band transmitted by the glass of the bulb.

Extending for a few thousandths of an inch from the cathode surface is a region filled with excited and ionized zirconium vapor and argon gas. The radiation from this, the cathode glow space, has three components; a continuum extending from the short ultraviolet to about 0.5 micron; the normal, singly, and doubly-ionized zirconium line spectra; and the normal and singly-ionized argon line spectra. Most of the zirconium lines occur in the ultraviolet part of the spectrum while the strongest argon lines are concentrated in the infrared, peaking around 0.8 micron.

When the current through the lamp is modulated at audio frequencies, a substantial part of the radiation also is modulated. A comparison shows that, as the modulating frequency is increased, the amplitude of the continuum, which originates from the cathode surface, decreases rapidly. The line radiation from the cathode glow space, however, decreases but little with increase in modulating frequency.

The greatest amount or quantity of modulated radiation is found in the spectral region between 0.7 and 1.0 micron. This is the portion of the spectrum which is adjacent to the visible on the long wave or infrared side. A second and much smaller peak of modulated radiation occurs in the ultraviolet region centering around 0.35 micron.

The long wave region offers several advantages as the spectral band in which to operate a light beam communication system. Caesium-silver-oxide types of photoelectric cells, which have the high sensitivity and good audio-frequency response required of the detector or receiver of modulated radiation in the system, reach

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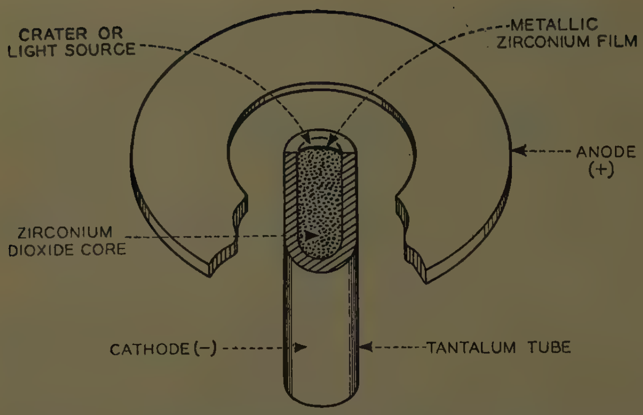

Figure 1. Internal construction of the concentrated-arc lamp

their maximum sensitivity in this region. A second advantage lies in the fact that this portion of the spectrum is not visible. Thus, the visible part of the radiation of the lamp may be removed by an infrared-transmitting colored-glass filter to make the signaling beam invisible with but little loss. A third factor which makes the infrared more desirable than the ultraviolet or visible regions lies in the spectral-transmission characteristics of the atmosphere which shows less attenuation under conditions of haze as the wave length of the radiation employed is increased.

At present, concentrated-arc lamps are made in sizes ranging from 2 to 100 watts (Figure 2). A 2-watt lamp has a source spot which is only 0.003 inch in diameter and has a maximum brightness of 62,000 candles per square inch. As the lamp wattage increases, the size of the luminous crater of the lamp grows larger but the brightness is less. Thus, the choice of which size lamp to use for a particular light beam communication system will depend upon the characteristic most desired.

Theoretically, the intensity of the beam of radiant energy will depend upon the brightness of the source and the diameter of the projecting lens while the width or spread of the beam will depend upon the diameter of the source and the focal length of the lens. A 2-watt lamp being the brightest should project the most intense beam and the one capable of being received over the longest distance. If perfect optics could be secured, this would be the case in practice, but the extremely small source diameter of the 2-watt lamp puts the accuracy of the projecting lens or mirror to a severe test. Thus, unless a very accurate lens is used some of the larger wattage and less brilliant lamps may give the stronger beam. The small source diameter of the 2-watt lamp does result in extremely narrow beams. For example, a 2-watt lamp, if sharply focused with a perfect lens which has a focal length of one foot, should project a beam which, at a distance of one mile, would be only 16 inches in diameter. Actual lenses are good enough to produce beams which approach this value. The beam width in this case is less than one minute of arc. Aiming such a beam requires an accurate sighting device, micrometer adjustments on the pointing mechanism, and very rugged and stable mounts.

If a 100-watt lamp were to be focused sharply with the same 1-foot-focal length projecting lens, the beam would be 312 inches or 26 feet in diameter at a distance of one mile. This beam has a spread of 17 minutes of arc, which is also a very narrow angle, so sturdy mounts and accurate micrometer controls still are required. The sharpest and most intense beam is produced when the lens is adjusted to focus the image of the source spot at the distant receiver which is, in most cases, a focus for infinity. Broader beams can be produced by placing the source inside the principal focal point of the lens, but in such cases, the brightness of the beam will decrease in almost exact proportion to the increased cross-sectional area of the beam.

Concentrated-arc lamps are thus most suitable for narrow-beam systems. The 2-watt lamps are best for use on long distance light beam circuits between fixed points where sturdy mounts and accurate lenses can be provided. Larger lamps are more suitable for use in portable equipment or other types of service where greater beam spreads are required. All sizes of lamps can be employed in very short throw wide beam systems.

The modulation characteristics of the small-wattage lamps are superior to those of the large. Modulation ratio is defined as the ratio between the per cent candle power change and per cent current change.

The per cent modulation ratio decreases with the increase in modulating frequency, the wave length of the spectral region employed and the lamp wattage. A 2-watt lamp, for example, will give percentage modulation ratios of 76 at 200 cycles, 63 at 1,000 cycles and 49 at 5,000 cycles if measured with an antimony type of photoelectric tube, which responds chiefly to the blue and ultraviolet radiation. A photoelectric cell of the caesium-silver-oxide type, which utilizes the longer wave radiation, will show percentage modulation ratios of 35 at 200 cycles, 25 at 1,000 cycles and 17 at 5,000 cycles. The shorter wave length radiation can be more completely modulated, but the amount or quantity of

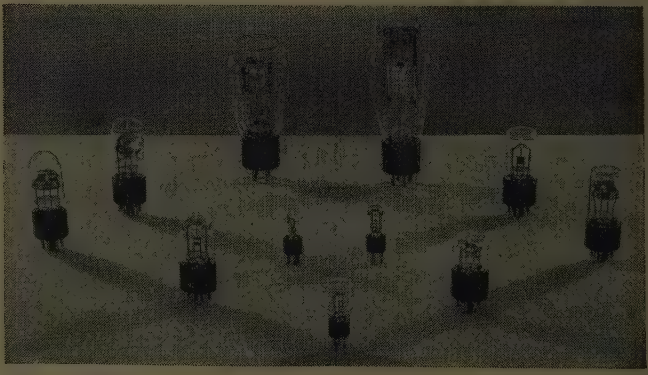

Figure 2. Various types and sizes of concentrated-arc lamps

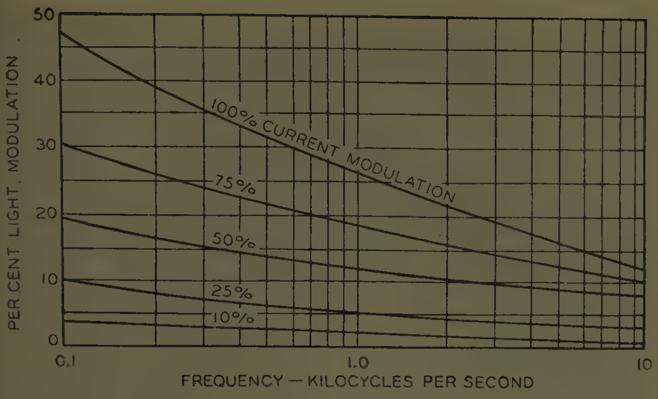

Figure 3. Frequency characteristic of 2-watt concentrated-arc lamp taken with a caesium photoelectric tube

modulated radiation, which is the important factor for light beam communication systems, is much greater in the longer, near-infrared region. A 100-watt lamp shows less than one half of the percentage light modulation of a 2-watt lamp. Because of its much greater output, however, the total modulated radiation of the 100-watt lamp is many times that of the 2-watt lamp.

As compared with a 100-watt argon-filled lamp, a krypton-filled 100-watt lamp shows a gain in modulation ratio of 56 per cent from the antimony or blue-sensitive photoelectric cell and a gain of 21 per cent from the red-sensitive caesium photoelectric cell.

The complete modulation characteristic of a 2-watt argon-filled concentrated-arc lamp when measured with a caesium photoelectric cell is shown in Figure 3. Larger wattage lamps have the same type of characteristic curves. At 100 per cent current modulation, this 2-watt lamp has a drop in output of 11.5 decibels between 100 cycles and 10 kc. The uniformity of the spacing of the curves for the various percentage of current modulation indicate a fairly linear relationship between modulated light output and modulating current.

The dynamic relationship between the lamp current and the lamp light is not absolutely linear. While the light output follows the current accurately on the peaks of the modulation cycle, it does not do so as the current and the light approach zero on the opposite half of the cycle. The resulting distortion of the modulated light wave is found from analysis to consist largely of the second harmonic of the modulating frequency. For this reason, the per cent of second harmonic frequency in the modulated light wave is used as a measure of the distortion of the lamps.

Per cent distortion tends to rise with an increase in the per cent of current modulation, the lamp wattage and the modulating frequency.

Impedance and phase characteristics of the 2-watt concentrated-arc lamp cause it to act as an inductive load. As the frequency increases, the impedance at first decreases, reaching a minimum of 150 ohms at 1,200 cycles, and then rises to 270 ohms at 10 kc. Its average value over the audio frequency range is about 200 ohms. The resistive component of this impedance has a negative value at low frequencies. This is a normal characteristic for arc lamps and is the reason why a ballast resistance always must be connected in series with the lamps to insure stability. At frequencies of 2,600 cycles and above, the resistance is positive. Current lags the voltage by an amount which decreases as the frequency increases, and the light lags the current, the phase angle increasing with the modulating frequency.

A summary of the impedance and phase characteristics of all the different sizes of concentrated-arc lamps shows the impedance of the lamps and the frequency, at which the resistive component of the impedance becomes positive, decrease as the lamp wattage increases. The phase angle decreases with the increase in lamp wattage.

These impedance characteristics must be considered in the design of modulators for the lamps. For example, the 2-watt lamp has a negative resistance at frequencies less than 2,600 cycles. If this lamp is connected into a circuit whose natural resonance is less than 2,600 cycles and if the positive resistance of the circuit is less than the negative resistance of the lamp, the circuit will oscillate. Thus, resistance must be added to some circuits to secure stability.

Lamps of the 2-watt size can be modulated by connecting them directly into the plate circuit of the modulator vacuum tube, the modulating voltage being applied to the grid, as shown in Figure 4. The direct current required to maintain the arc is supplied by the normal plate current of the modulator vacuum tube.

Larger wattage lamps require a modulator circuit where an impedance matching transformer is used to couple the lamp to the modulator and the direct current for the arc is obtained from a separate supply source.

Since April 1943, an experimental light beam telegraph circuit using concentrated-arc lamps as the source of the modulated radiation, has been in operation over lower Manhattan. The circuit runs from the main

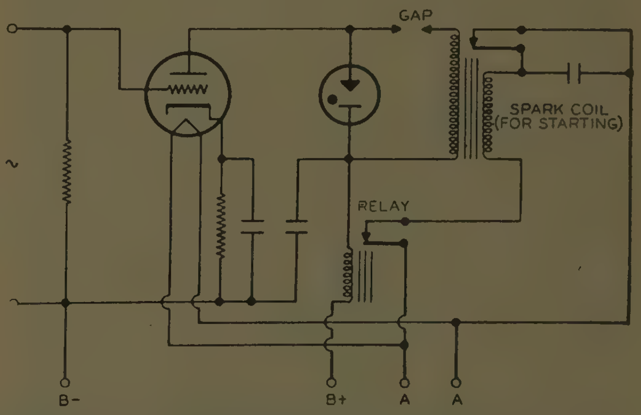

Figure 4. Direct coupled modulator circuit for a 2-watt concentrated-arc lamp

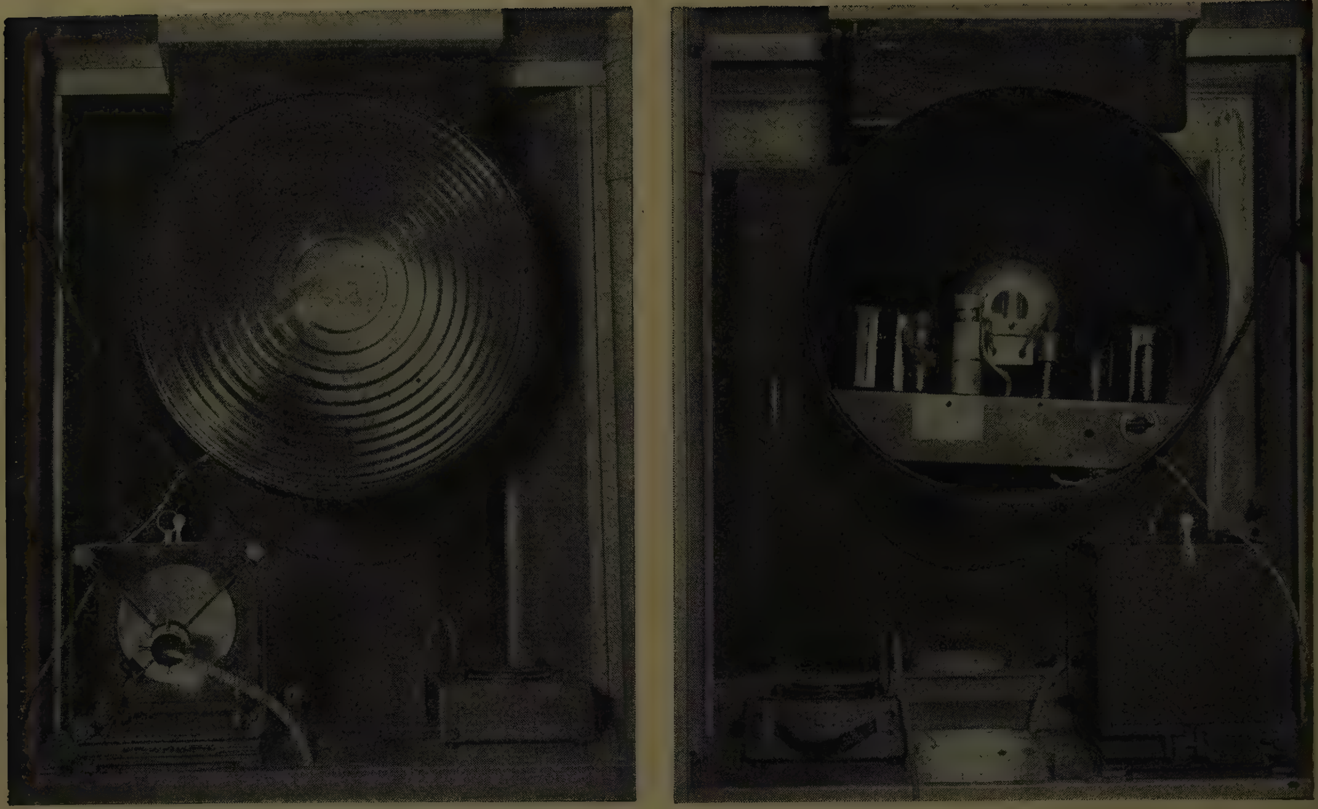

Figure 5. Front view (left) and rear view (right) of concentrated-arc transmitter (bottom) and receiver (top)

Western Union office to a branch office, an air-line distance of about three quarters of a mile. A teleprinter-telegraph circuit operating at 65 words per minute is carried by two light beam systems, one operating in each direction.

Figure 5 shows the light beam transmitting and receiving equipment at one end of this circuit. The transmitter, which is the smaller of the two units, consists of a 10-watt concentrated-arc lamp whose radiation is focused on the distant receiver by a parabolic mirror of good optical quality, which is six inches in diameter and has a 6-inch focal length. This combination produces a beam which is about ten feet in diameter at the distant receiver. Since the beam is so narrow it has not been thought necessary to filter out the visible radiation so as to use only the infrared portion to obtain an invisible and more secret beam. The receiver unit utilizes a molded Fresnel lens 18 inches in diameter to collect the radiant energy received from the distant transmitter and to concentrate it on a high-vacuum-type caesium-silver-oxide photoelectric cell. This equipment operates unattended. It is started and turned off from the circuit operating positions and requires only occasional attention. The 10-watt concentrated-arc lamp in this transmitter had operated over six months at the time of this writing.

To the camera and to the eye, the distant transmitting lens appears to be many times its true diameter because of its extreme brilliance. Movement but a few feet in any direction from the center of the incident beam causes the spot of light to disappear.

If the transmitter lens on this circuit were absolutely perfect and the atmosphere absolutely clear, there would be a signal loss over this 3/4-mile distance caused by the spreading of the beam, which would amount to 17 decibels. Calculations indicate that under ideal conditions, this system should operate up to about 30 miles. Under actual conditions, the additional loss due to lens imperfections and atmospheric conditions may be considerable. On a very clear night the received signal on this light beam circuit is 56 decibels above the noise level. In daylight, the noise increases so that the signal is 50 decibels above the noise. Sunshine, clouds, and light haze have little effect although heat waves or striae in the air may cause some fluctuation of the received signal. A light rain may cause the signal to drop 10 decibels and a very heavy rain 20 decibels. A moderate fog may reduce the received signal 30 decibels while a very heavy fog or snowstorm will interrupt the circuit.

During the $3^{1}/_{2}$ years that this circuit has been under test 9 hours a day 5 days per week, it has operated 96.7 per cent of the time. Of the 3.3 per cent lost time, 2.8 per cent was due to trouble in the equipment on the light beam section of the circuit. This figure is of the same order as might be expected with any experimental apparatus. The remainder of the lost time, or 0.5 per cent, was caused by interruptions to the light beam by fog, heavy snow storms, and smoke. Ordinary atmospheric haze caused no interruptions as the near-infrared radiation in the beam does pierce this type of diffusing medium better than visible light.

The attenuation or scattering of the beam depends upon the relative size of the suspended particles which make up the haze or fog and the wave length of the radiation employed. If the radiation has a wave length which is large in relation to the diameter of the particles, little scattering will occur. As the diameter of the particles approaches the magnitude of the wave length of the radiation, the attenuation rises rapidly. Fog particles may have diameters as much as 25 times as great as the wave length of the radiation employed in this equipment. As a result, the attenuation due to fog is very great and in very dense fogs it is impossible to produce a beam of radiant energy from a concentrated-arc lamp which will operate a light beam communication circuit for more than a few tenths of a mile.

Concentrated-arc lamps thus are seen to have characteristics which fit them for use as sources of modulated radiation and particularly for narrow-beam communication circuits. Such circuits can be employed over short distances with good dependability. Long distance circuits, limited only by the optical range, should be possible in fog-free localities.

New Airplane Catapult

The "electropult," an unusual type of induction motor manufactured by the Westinghouse Electric Corporation, Pittsburgh, Pa., is designed for launching airplanes that require long take-off runs from small landing fields without the high inertia impact imparted by other catapults. The secondary winding of the motor is the track of the catapult, and its primary winding is the car to which the airplane is harnessed.

Two electropults are now in use by the Navy, one at Mustin Field, Philadelphia, Pa., and a larger one at the Naval Air Test Center, Patuxent River, Md. The track of the larger unit is 1,382 feet long, and is made up of 76 sections with 12-inch active core width, that are set flush with the surface of the runway. Resistance of the first 1,000 feet of track is decreased progressively in four steps. This graduation of resistance enables the tractive force to be held substantially constant as the speed is increased. The last 382 feet are used for stopping the car by dynamic braking and application of direct current.

Jet-propelled fighter airplane being prepared for launching by the Westinghouse "electropult," a linear induction motor

The car projects only $5^1/_2$ inches above the surface of the runway. On the under side of the car is the 3-phase primary winding in a flat core at a working air gap of 3/16 inch. The car wheels run on rails recessed in slots which straddle the stationary secondary winding, and a set of rails above the wheels prevents the car from being lifted. A space under the track houses the bus bars and collector rails that carry approximately 7,000 amperes during acceleration and 10,000 amperes during braking. The current collecting problem is extremely difficult because the car attains a speed of 225 miles per hour. The 12 collector shoes per phase are held against the collector rails by spring pressure. Provision is made for the pilot of the airplane to release the harness at the proper time.

One of the features of the launcher is a short-time power demand of approximately 12,000 kw. The power supply consists of a 2,200-horsepower aircraft engine coupled to a 750-kw d-c generator which supplies a d-c motor connected to a 24-ton flywheel and 3-phase alternator that supplies the catapult car. During the short time required to launch an airplane, the flywheel loses speed to furnish approximately 95 per cent of power needed. Slowing down of the flywheel and alternator reduces the frequency from 216 to about 192 cycles per second.

The electropult has launched jet-propelled airplane at 116 miles per hour in 4.1 seconds after a run of only 340 feet. Unassisted, the same airplane requires a take-off run of approximately 2,000 feet.

Copperspun Squirrel-Cage Rotor

G. R. ANDERSON
MEMBER AIEE

The name "Copperspun" describes a 1-piece squirrel-cage rotor cast of copper by a centrifugal process. Salient features of the rotor are: high strength, high melting point, no joints, low coefficient of expansion, high conductivity, low porosity, and improved dynamic balance.

INVENTION of the induction motor was a major factor in the early change from direct to alternating current. Since that time the squirrel-cage type of induction motor has passed through a natural evolutionary development. This particularly applies to the design, construction, and manufacturing technique of the squirrel-cage winding.

The squirrel cage is the simplest of all windings, yet it must carry many thousands of amperes at low voltage and must be rugged in construction for both mechanical and electrical reasons.

Many different types of rotor construction have been used through the years; some of the earlier types were designed with rotor bars soldered to circular end rings. Some rotors were made with bars bent and riveted together on each end. One type of rotor was a modified cast enbloc design in which copper bars were inserted in the rotor slots and the end ring cast around the extension of each bar. Other types of rotors using copper or copper alloys employ rolled bars, brazed with bronze or silver, soldered to brass or copper end rings.

One-piece cast en bloc squirrel-cage windings have been in production for over 25 years. Several different methods of casting 1-piece rotors are in use, such as gravity casting, pressure casting of one form or another, and centrifugal casting. The majority of rotors built by these methods used aluminum or low temperature alloy metals. The use of copper and copper base alloys in the 1-piece en bloc rotors has been produced successfully only in the last few years.

There is no question regarding the principle that the 1-piece cast en bloc rotor is the ideal construction. Limitations in its use have been due entirely to materials or manufacturing processing problems.

Aluminum or white metal alloys have been used for 1-piece squirrel-cage windings with a variety of processing methods since the difficulties in manufacture were not unduly restrictive with low melting point metals. These processes, however, do not all produce the maximum in physical characteristics or electrical conductivity. Centrifugal casting is a preferred process from the standpoint of grain structure and casting porosity. This is verified by the improvements that have been made in centrifugal casting of iron and steel, such as the brake drums for automobiles, to obtain a tough long wearing structure. The successful centrifugal casting of high-temperature metal such as copper or copper alloys has been the result of the solution of a number of manufacturing problems involving the following basic requirements:

1. The laminated cores must be stacked and held under pressure in order to produce satisfactory slot recesses for the squirrel-cage winding.

2. Casting pressures must be sufficiently high to produce a dense nonporous structure of high conductivity and high strength. One of the advantages of centrifugal casting is the fact that pressure is controlled easily by adjustment of speed.

3. In the technique of casting, the copper must remain fluid a sufficient length of time to permit all recesses in the mold structure to be filled properly.

4. The design of the winding structure should be such that where change in section occurs, fillets should be used to avoid stress concentration.

5. There must be complete absence of fusion between copper and steel; otherwise there will be an alloying action between these elements that will cause a reduction of conductivity.

In actual practice compression of rotor laminations during processing may be obtained by several methods. One method in successful use employs air pressure against both ends of the assembled core, the pressure being maintained while the core is spun during casting. Another method employs centrifugal action to produce a positive pressure against the core during casting.

When centrifugal casting is used to obtain high density and ductile casting structures, the only limitation in the developed pressure is the maximum speed at which the structure can be rotated. In actual practice, Copperspun rotors are produced with centrifugal casting speeds running as high as 4,000 rpm.

Maintenance of fluidity of metal for a sufficient length of time to fill completely all recesses in the rotor and mold structure is obtained by maintaining balanced temperatures between the various parts of the metal and mold

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Essentially full text of paper 47-206, "The 'Copperspun' Squirrel-Cage Rotor," presented at the AIEE Middle Eastern District meeting, Dayton, Ohio, September 23–25, 1947, and scheduled for publication in AIEE *TRANSACTIONS*, volume 66, 1947.

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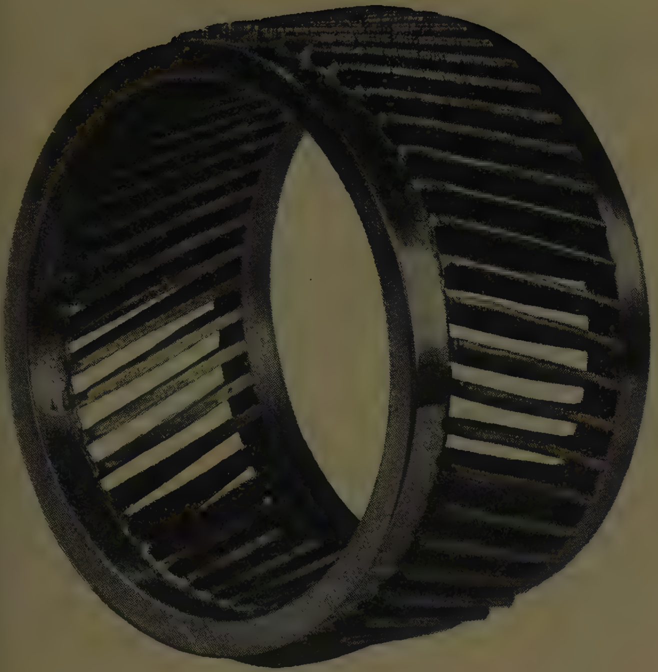

Figure 1. Copper squirrel-cage winding disassembled from the magnetic core illustrating absence of fusion

structures. Molten copper at a given temperature requires a temperature relationship between the core and mold surfaces, with which the copper comes in contact, of a degree which will permit the copper to remain a fluid only for a sufficient length of time to fill completely all recesses in structure.

The use of high-frequency induction furnaces for melting copper has been excellent for the control of metal temperatures and maintenance of chemical purity. Automatic devices in general industry use provide satisfactory control for core and mold temperatures to create the necessary balance for successful casting.

The shrinkage allowances for cast copper, thermal expansion, and modulus of elasticity all favor the use of copper over aluminum. As a result the problem of shrinkage and stress concentration in the 1-piece copper rotor is much less pronounced even though casting temperatures practically are doubled. Rotors should be designed with large fillet radii between the bars and end rings to give maximum ruggedness and strength. The high conductivity of the copper rotor with the resultant increase of magnetic sections gives greater freedom in the design and shape of the rotor slot.

The requirements for momentary fluidity in cast en bloc structures accentuates the possibility of fusion between steel and copper with the ultimate detriment to electrical characteristics of the copper windings. Thus means must be provided for the prevention of fusion and pickup of chemical impurities. This is accomplished by sinterizing a silicate surface to the laminated core, and by designing the molds with nonferrous surfaces that come in direct contact with the molten metal. This is particularly important where there is a flow of metal over the surface. The attainment in the control of fusion in the Copperspun rotor is evidenced by the fact that conductivity of the order of 90 per cent that of pure copper is obtained in the cast structure. This is nearly twice the conductivity of the purest aluminum.

High slip squirrel-cage rotors, such as required for hoist and elevator motors, are fabricated the same as pure copper rotors, by the addition of alloying elements. Alloying is done in separate crucibles where quantity runs warrant, or it may be accomplished for an individual casting operation by the addition of the necessary alloy agent prior to actual pouring. Experience has proved that the fabrication of a copper alloy rotor offers no particular complication and that conductivity can be controlled closely through a wide range with a single alloying agent.

The use of copper in 1-piece squirrel cage rotors not only provides a rotor of high mechanical strength, but the high conductivity that is obtained permits the designer a greater freedom in choice of the electromagnetic circuit. Aluminum is not used in the stator because it would require slots nearly twice as large as those necessary for copper wire. By the same token, the slots and bars of the rotor can be considerably smaller with a resultant low magnetic density in the teeth and core of the rotor. This is more important in the design of double cage rotors. The high fluidity of copper permits a narrower neck in the slot between the outer and inner cages. This narrow neck in turn results in a reduction in the distance between the two cages; in other words, the lower cage can be brought nearer to the surface of the rotor. As a result of the reduction in slot space of the inner cage it is possible to obtain improved speed-torque characteristics without the necessity of resorting to devices such as criss-crossed rotor slots.

The high conductivity of the Copperspun rotor also is a factor in reduction of stray load losses. The selection of slot combination is, of course, one of the major factors in control of stray losses, but since the use of high conductivity material permits a maximum freedom of design,

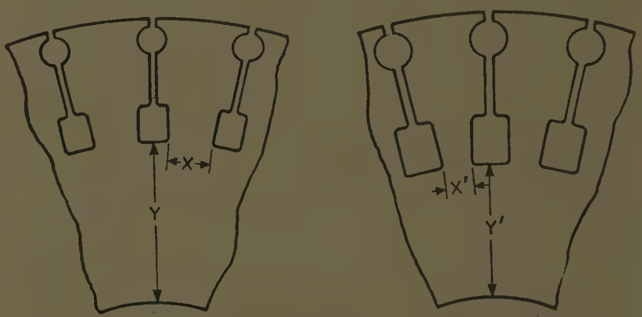

Figure 2. Double cage slots for Copperspun (A) and cast aluminum (B) rotors

Magnetic flux density at X approximately 35 per cent lower than at X'
Magnetic flux density at Y approximately 20 per cent lower than at Y'

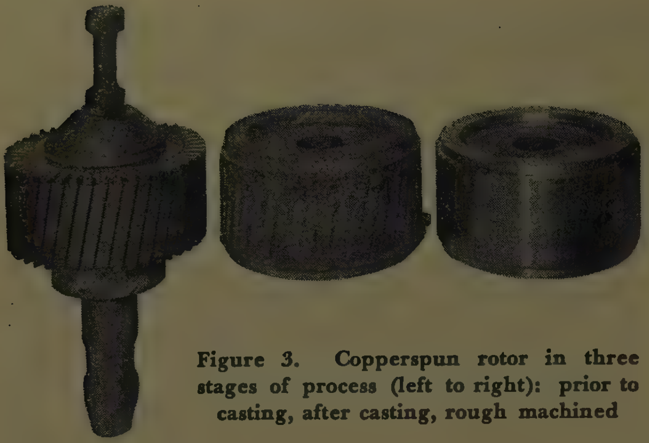

Figure 3. Copperspun rotor in three stages of process (left to right): prior to casting, after casting, rough machined

the shape and number of slots can be selected to best advantage. Further, stray load losses due to surface currents in the squirrel-cage winding are reduced in proportion to the increase in conductivity.

It is possible to design the mold and casting structure to provide fans cast integral with the rotor. This is a general practice with aluminum rotors. The Copperspun rotor, however, is equipped with separately mounted fans. This permits complete over-all machining of the rotor and provides improved means for checking the quality of production and improving the dynamic balance of the finished product.

The performance record of the Copperspun rotor has been proved in service of the severest nature. One particular example is its application to reversing duty where rotor troubles are largely predominant. The slightly higher weight of copper is more than offset by the increase in ruggedness and strength and the ability to withstand higher rotor temperatures. Further, the inertia of the rotor which is a major factor in the application of motors to reversing service is more dependent on the diameter of the rotor than on the weight since the inertia is proportioned to WR^2 which means that a reduction in diameter to obtain lower inertia is much more important than any slight reduction in weight.

X-Ray Protection

An extensive program for determining the effectiveness of concrete as a protective barrier against million-volt wide-beam X rays is being conducted by scientists at the National Bureau of Standards. Optimum wall thicknesses and most desirable types of construction necessary for maximum short wave length X-ray protection are being investigated.

Broad beam X rays which allow simultaneous examination of wide areas have come into extensive use for detecting flaws in all types of metal, and have created a special personnel protection problem. When a broad X-ray beam enters a thick concrete wall, it is scattered and rescattered many times with the result that a considerable fraction of the beam emerges on the other side, endangering personnel. Quantitative information on the amount of this scattering is part of the present investigation program.

To determine protection standards, a 1.5-million-volt X-ray machine has been converted so that it will produce beams of varying widths. It is mounted so that it can be directed downward into a radiation pit about six feet square and 20 feet below the target of the X-ray tube. Special instruments that can be shifted to various positions by remote control are used to explore the strength of the radiation in the pit. Both the control and the X-ray reading equipment are operated from a central control room surrounded by 18 inches of concrete and located 75 feet from the radiation pit.

Test slabs of concrete, each weighing $2^1/_2$ tons and measuring six inches in thickness, are placed over the mouth of the pit one at a time, thus enabling investigators to vary the protective barrier from six inches to five feet in thickness. Since space and weight are of critical importance in many installations, arrangements also have been made for producing "sandwiches" of lead and concrete in alternate layers. At present, the best proportions between these two materials are entirely unknown.

Among the problems being investigated is the shielding of such machines as betatrons that operate at 50 million to 300 million volts. Because the beams emerging from such machines cover a very small angle (for the 50 million-volt betatron the angle is six or eight degrees), it may be possible to simplify the shielding problem.

For the direct beam, a very great thickness of concrete may be required. On the other hand, rays which are scattered sideways out of this beam are of a very much less penetrating character, and so it may be found that the protection problem for the side of the beam may not be seriously different from that at one or two million volts.

The collection and evaluation of data obtained in this investigation program can bring about sufficient protection at maximum economy. That the economic phase of high-voltage X-ray shielding is important is indicated by the fact that the cost of protection alone in a 50-million-volt medical or industrial installation may represent half to three quarters of the total cost of the equipment.

Paper Mill Power Ties

A. P. SCHNYDER
MEMBER AIEE

Power ties to pulp and paper mills provide standby capacity for the mills, supply them with essential services during protracted shutdowns, and sometimes the tie can operate in reverse to the benefit of the utility. In regions where fuel is available at moderate cost, power ties are limited to carrying a marginal amount of power not available as by-products from process steam passing through mill turbines.

DURING World War II the paper industry, except for the packaging branch, was classified as a nonessential activity with the result that expansions were discouraged and cut to a minimum. The great number of projects under construction during the last two years is an indication to what extent the war throttled paper mill expansion. Only a few of these new mills have started production to date so that the rate of increased production is not yet in swing.

Paper mills can be classified into three types: the pulp mill which converts the raw materials—wood, rags, straw, Manila fiber, and old rope—into paper pulp; the paper mill which converts the pulp into paper or paper board; and the integrated mill which combines the first two types into one continuous operation.

In 1946 United States mills produced 10,615,000 tons and imported from Canada 1,235,000 tons of wood pulp, and for the balance of production used 8,100,000 tons consisting of 85 per cent waste paper, 6 per cent rags, 6.5 per cent straw, and 2.5 per cent miscellaneous. Total output of paper and paper board with the aforementioned materials amounted to 19,157,000 tons. Canada's production for the same year was 4,143,000 tons of newsprint, relatively small amounts of diversified paper, and 1,300,000 tons of wood pulp for export.

The 1945 power consumption for the entire United States paper industry of 11,444,689,000 kilowatt-hours placed it in fourth place of the manufacturing industries and accounted for 4.2 per cent of the total production of electric energy for both public and private use. The paper mill average load totaled 1,500,000 kw and was supplied with more than 2,000,000-kw generating capacity. The proportion of the load carried by utilities was not stated but one can guess that it was less than one quarter of the total.

Most United States mills combine their demand for steam and power in fuel-fired plants, which burn fuel oil, coal, natural gas, and by-products. Hydroelectric power is generally unavailable. Except for newsprint mills which require from 60 to 70 per cent of the power used for the production of groundwood pulp, integrated mills, particularly kraft paper and paper board mills, have an ideal proportion in demand for power and process steam. By the use of suitable extraction-type turbogenerators and high-pressure and high-temperature (400–850 pounds per square inch, 600–800 degrees Fahrenheit) steam generating plants the amount of condensing steam for power generation can be kept to a minimum. The by-product power obtained in passing process steam from the boilers through turbines, which act as pressure reducing valves, can be generated with 5,000 Btu per kilowatt-hour, whereas the most efficient central station uses 10,500 Btu per kilowatt-hour. Power generation almost wholly by process steam is practiced in quite a number of mills for extended periods of operation. Condensing power still is necessary for marginal fluctuations, occasional outages in some departments, but mostly during shutdown and starting of operations.

The primary economic function of a power tie with a utility where the mill generates steam and power is to have the utility supply whatever condensing power is necessary with the provision for power flow in both directions. Then all available by-product power at its low heat rate is used. The utility plant can be expected to generate condensing power more efficiently, competently, and reliably from an operating standpoint. In a paper mill power generation is incidental whereas for the utility it is the primary function.

Older mills predominantly use utility power unless they have remade their steam generating plants into efficient high-pressure stations to avail themselves of the best possible process steam power balance. Low-pressure steam plants do not warrant installation of extraction turbines. Some mills keep their old condensing type turbogenerator units for emergency stand-by in case of utility failure, but such practice is of doubtful value. Another class of mills which produce small tonnages of highly specialized papers use utility power as a matter of operating balance economy.

The great majority of pulp and integrated mills limit the power tie, when used, to a stand-by source in case of mill power plant failure, and to supply the mill with

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Essential substance of conference paper, "Power Tie With Utility," presented at the AIEE summer general meeting, Montreal, Quebec, Canada, June 9–13, 1947.

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special services during protracted mill shutdowns. Sometimes the capacity of a power tie can be boosted to supply enough power while a turbogenerator is down for overhaul. The tie can operate in reverse as well, benefiting the utility, especially where it has a long line to supply the mill and its community. If necessary the mill can cut back its production rate to maintain all essential services of the town.

One of the major paper manufacturing companies operating large mills in several states has an unusual utility tie in its newest mill. The power company built the power plant adjacent to the mill site but located some of the generating units in a turbine room within the mill proper. The utility steam line connects with the mill turbine room, and the utility buys steam from the mill which generates it as a by-product in the process of recovering chemicals.

The tie for an integrated mill is an engineering inconsistency because the mill must be isolated geographically to be located near the center of the pulpwood supply area. Such regions are settled relatively sparsely, sometimes outside the economic reach of the utility's distribution system, whereas mill power could supply the population which brings in the crop of pulpwood.

The most serious objection to the power ties for supplying process power is possible line outages. The longer a transmission line, the more likely is a power interruption caused by lightning, wind, ice, or other natural causes. Power failures are costly for mills in loss of production and spoilage.

In Canada, the relation between paper mills and utilities is radically different from that in the United States. Whereas newsprint in the United States annual paper production amounts to only 4 per cent, Canada's newsprint accounts for some 80 per cent of its total paper production. Newsprint uses from 85 to 90 per cent groundwood (mechanical) pulp and from 10 to 15 per cent of sulphite (chemical) pulp. The groundwood pulp absorbs from 65 to 70 per cent of the mill power demand. Where mills have fuel-fired steam plants to supply process steam, noncondensing turbogenerators can provide about the balance of power required by the paper and chemical pulp department so that the tie with the utility must carry only the groundwood department. In such mills outside power interruptions are relatively inconsequential.

Storage capacity for groundwood pulp is made extra large to hold the output of the grinder room during Sunday shutdowns while only a skeleton crew of operators is required, because hydroelectric power would go to waste if not used for this purpose. Another outlet of Sunday's surplus power is through electric boilers for mill heating.

Where the developed water power capacity is so plentiful in certain Canadian areas, utility systems have sufficient secondary power to carry the mills. Electric boilers convert electric energy from hydroelectric plants into process steam at mills some distance from the power plant site. Although line outages will shut such mills down, operating conditions with electric boilers compared to standard steam plants are very convenient and simple.

The power tie to paper mills seems to be essential in regions of hydroelectric power where the cost of fuel is high enough to render steam power generation comparatively unprofitable. In mills having up-to-date power plants with fuel supplied at moderate cost, the usefulness of the power tie is limited to securing the marginal amount of power not available from process steam passing through turbines. In most cases, however, it is the source of stand-by power.

Self-Contained Transformer

This 100,000-kva transformer, product of the Westinghouse Electric Corporation, is said to be the largest self-contained unit of its type ever built. The complete unit stands 21½ feet high, weighs 124 tons, and required 185,100 pounds of steel for its construction. In order to ship it in an ordinary flat car, the oil-cooled transformer had to be turned on its side and its radiators and bushing removed

High-Voltage Power Distribution

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General acceptance of load center power distribution for 480-volt and 600-volt loads, and the trend toward higher voltages for large motors have increased greatly the importance of high-voltage distribution systems. Paper mills frequently have a large portion of the total load in large motors operating at the high-voltage level, and therefore the fundamental considerations of the high-voltage systems are more complex than in many industrial establishments where all loads are at the 600-volt level.

UNIQUE problems of power distribution are encountered in the pulp and paper industry which may be classed as one of the major power consumers on the North American continent. The importance of the pulp and paper industry to Canadian economy cannot be overemphasized. Up until 1934 this industry ranked first in Canada in gross value of its products. During the war years, artificial conditions pushed it to fifth place in 1944, the last year for which figures are available, but since the close of the war it has been coming back to its former premier place.

Newsprint from groundwood mills is the main Canadian product. The United States absorbs 80 per cent of Canadian pulp production and over 75 per cent of Canadian paper production, while approximately one half of all the paper consumed in the United States is either of Canadian manufacture or is manufactured in the United States from Canadian pulp.

In the United States, the majority of mills are either sulphite or sulphate pulp mills for the production of kraft and specialty paper. Groundwood mills, which are the basis of the Canadian newsprint industry, are in the minority.

Groundwood mills consume great amounts of electric power, usually in the neighborhood of 75 kw per ton-day. Since Canada has available large quantities of relatively low cost electricity generated from water power, this type of production is suited well to Canadian conditions. While some of the Canadian groundwood mills have their own water-wheel generators and a few have their own steam turbine generators, the bulk of the power is purchased. The Canadian pulp and paper industry purchases approximately 50 per cent of all the power sold for industrial purposes by the central station industry.

In the United States it is usual for a paper mill to generate its own power by steam and to have a connection with a utility for emergency or off-peak power. The exhaust steam from the power generating turbines provides at least part of the considerable amount of process steam required; but in Canadian mills where power is purchased, separate provision must be made for process steam. Paper mills in Canada purchase power at anywhere from $14 to $20 per horsepower per year and, under normal conditions, secondary or off-peak power has been available at $7 to $8 per horsepower per year. It is economical to use this secondary power to generate steam in electric steam boilers. This practice has been curtailed during the last few years due to the power shortage, but undoubtedly will be resumed as installed generator capacity catches up with demand.

The large groundwood mills, which produce pulp mechanically, use many large grinder motors in the 2,000–5,000-horsepower range. These motors usually present distribution problems not encountered in sulphite and sulphate mills where power is used at low-voltage levels. It should be noted, however, that newsprint contains from 15 to 20 per cent sulphite pulp so that a so-called groundwood mill involves production of sulphite as well as groundwood or mechanical pulp.

Pulp and paper mills range in size from the very small specialty paper mill with a total power requirement of 2,000 kva or less up to the very large groundwood pulp and paper mill having power requirements of the order of 75,000 kva or more. Because of this great variety in the industry the ideal distribution system for any given plant should be developed from fundamental considerations rather than by adaptation from other installations.

VOLTAGE SELECTION

In selecting the desirable voltage level to use for high-voltage distribution in a pulp and paper mill the following factors should be given consideration:

1. Installed cost of the distribution system.
2. Cost of motors and control which must be operated at the high-voltage level.
3. Design and operating feasibility.
4. System losses.

Essential substance of a conference paper, "Power Distribution Systems for Pulp and Paper Mills—High-Voltage Power Distribution," presented at the AIEE summer general meeting, Montreal, Quebec, Canada, June 9–13, 1947.

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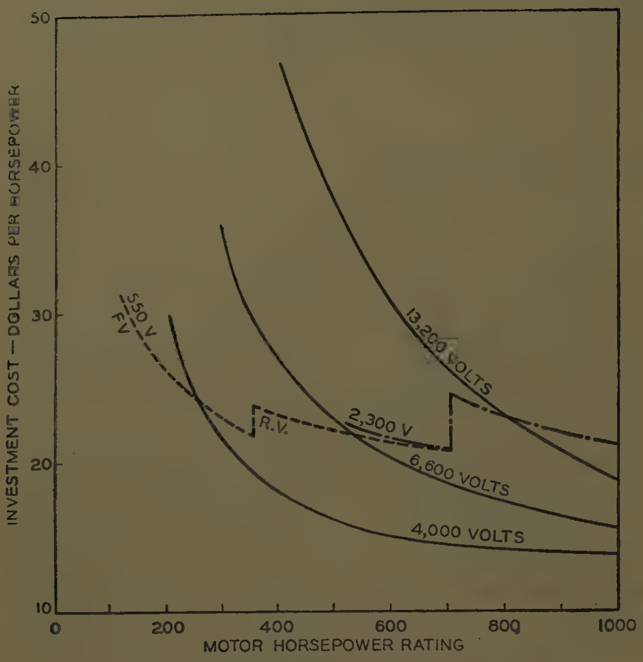


Figure 1. **Investment cost of synchronous motors**

——— *Motors and controls only for 4,000, 6,600, and 13,200 volts*

— — — *Motors and controls plus cost of substation capacity and capitalized losses for 2,300 volts*

- - - - *Motors and controls plus cost of substation capacity and capitalized losses for 550 volts*

Fv—Full voltage *Rv—Reduced voltage*

If the major amount of power is to be generated locally, or purchased from the power company at a voltage above 15 kv, then a decision must be made with regard to the voltage to be used for mill distribution.

It is recognized commonly that 2,300-volt motors and control are less costly than 4,000-volt motors and control. Consequently, where large motors are involved it frequently is concluded that 2,400 volts is the logical voltage to use for high-voltage distribution. Actually this results in a greater over-all system cost except in some cases where the large motors involved form the major portion of the load. Both switchgear and cables are more costly for a given system at 2,400 volts than at 4,160 volts.

The higher capacity circuit breakers are designed to interrupt a given number of kilovolt-amperes at rated voltage and at voltages down to 4,160 volts. At 2,400 volts the fault current corresponding to the circuit breaker kilovolt-amperes exceeds the maximum current interrupting ability of the circuit breaker. The "make rating" or ability of a circuit breaker to "make" against the peak current in the first half cycle after it is closed on a fault is the most severe limitation. Since the make rating in amperes is independent of voltage, the higher fault currents at 2,400 volts may require the selection of circuit breakers of a much higher rating than would be required at 4,160 volts. Or alternatively, it might be necessary to sectionalize the main bus with smaller generator or transformer units to reduce the maximum fault current. Either solution results in a greater overall cost at 2,400 volts than at 4,160 volts.

Large power cables for 2,400-volt or 4,160-volt service have a very small amount of insulation relative to the amount of copper and lead. Therefore, the cost depends much more on the cross section of copper required than on the insulation. As a result, cables to carry a given load at 2,400 volts cost approximately 50–80 per cent more than cables to carry the same load at 4,160 volts. This is on a thermal basis.

Because of the higher cost and limitations of 2,400-volt systems as opposed to 4,160-volt systems, experience has shown that 4,160 volts is the preferable voltage under nearly all conditions. The only exceptions might be: where the power is purchased from a utility at 2,400 volts; and where most of the power is utilized at the high-voltage level and where the load is very concentrated, requiring only very short 2,400-volt feeders.

Since it appears that 2,400 volts is an unsatisfactory voltage to use, the choice is narrowed to 4,160, 6,900, or 13,800 volts. Small paper mills with power requirements of the order of 2,000 kva find it most economical to generate or distribute at 460 or 575 volts directly. However, it is uneconomical to expand such a system beyond 3,000 or 4,000 kva. Systems utilizing 4,160 volts are economical up to at least 10,000-kva capacity and may be expanded up to 20,000 kva within the limits of good economic and engineering design. For systems above 20,000-kva capacity, 13,800 volts has been found correct and in fact it is best to use this voltage in the 10,000- to 20,000-kva range if expansion beyond 20,000 kva may be anticipated. In the United States standard switchgear voltage ratings are 5 kv and 15 kv, but in Canada the standard ratings are 7.5 kv and 15 kv. As a result, 6,900 volts is used commonly in Canada now.

Voltage recommendations are based primarily on systems where nearly all power is utilized at the low-voltage level. For systems where a large part of the load consists of large motors or other loads which may be operated more economically at the system high-voltage level, the proposed systems must be developed in considerable detail for the alternative voltages under consideration, and complete estimated costs of the alternatives prepared.

In most sulphite and sulphate mills the proportion of power consumed at the high-voltage level is relatively small and does not affect seriously the choice of voltage based on the afore-mentioned recommendations. However, in groundwood mills the high-voltage load usually is predominant and the choice of voltage depends much more on the economics involved in the selection of grinder motors and control and the part of the system required to provide power for them. It is best to adopt the voltage selected on this basis for distribution to the load center unit substations also, in order to provide for interchange of power between the portion of the system serving the grinder motors and the portion of the system serving load center units.

ECONOMICS OF MOTOR APPLICATION

In comparing systems at alternative voltages, or in the final design of a system, it is usually difficult to decide at what voltage level motors of the order of 250 horsepower and larger should be operated. The following recommendations are for the correct voltage level for motors of various ratings, in which the most economical application is the chief consideration, modified where necessary by limitations of good design practice.

Figure 1 shows the investment cost of synchronous motors and control. These curves were based on standard 60-cycle 1,200-rpm 0.8-power factor synchronous motors. For the 2,400- and 4,160-volt curves, standard control with current-limiting fuse protection was assumed, except that this type of control is limited to a maximum of 700 horsepower at 2,400 volts, and beyond that rating oil circuit breaker starters are used. Control for 6,900- and 13,800-volt motors was assumed to employ 250,000-kva oil circuit breakers. It has been demonstrated that a 2,400-volt system cannot be justified under most conditions, and the 2,400-volt curve is not included for purposes of direct comparison with the other high-voltage curves but because it is recognized that it may be desirable to transform from higher voltages to 2,400 volts for certain ratings of motors. The 2,400-volt curve therefore includes cost of substation capacity for transformation from 13,800 volts to 2,400 volts. Disregarding diversity the substation capacity was included at $5 per horsepower of motors served.

The investment cost of 2,300-volt motors where the distribution voltage is 13,800 volts includes the capitalized losses in the substation required to serve such motors. It has been assumed that the average power cost is $20 per horsepower per year on a peak load basis. Capitalized cost of losses has been added to the 2,400-volt curve.

The 575-volt curve was based on standard motors and standard motor starting equipment plus cost of substation capacity for transformation from the high-voltage level to the low-voltage level. On the basis of a load center distribution system employing 1,000-kva or 1,500-kva unit substations, this substation capacity may be evaluated at $8.50 per kilovolt-ampere. The diversity factor for low voltage loads in pulp and paper mills is such that one kilovolt-ampere of substation capacity will serve a connected load of 1.5 horsepower. This results in approximately $5.50 per installed horsepower for substation capacity.

Large motors in the pulp and paper industry are operated almost continuously as a rule and consequently the distribution system is subjected very infrequently to voltage dips caused by motor starting. It has been assumed that a voltage dip of 10 per cent is permissible when starting large motors on the low-voltage system. On the basis of a low-voltage load center distribution system employing 1,000-kva or 1,500-kva radial unit substations, 10 per cent voltage dip results from full voltage starting of a 350-horsepower motor. Consequently, the 575-volt curve includes the cost of full-voltage starting equipment below 350 horsepower, and reduced voltage starting equipment above 350 horsepower. Although these curves were prepared for 575-volt equipment, prices of apparatus are such that the results are directly applicable where 460 volts is used for low-voltage distribution.

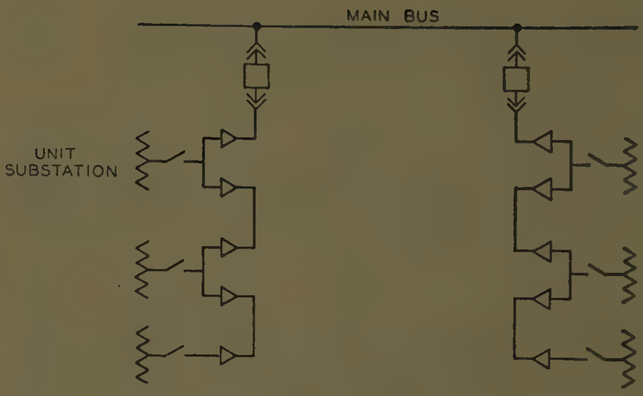


Figure 2. Single radial feeders

For a system employing 4,160 volts it is evident that motors up to about 250 horsepower should be operated at the low-voltage level and all motors larger than 250 horsepower should be rated 4,000 volts. For a system employing 6,900 volts, motors up to 500 horsepower should be operated at the low-voltage level and all motors above 500 horsepower should be rated 6.600 volts. Some motor designers are of the opinion that it is not possible to design a 6,600-volt motor below 800 horsepower without sacrificing part of the normal safety factor required for best design. Motors in the range of 500–800 horsepower could be operated at 2,300 volts and the total investment cost of motors, control, substation capacity, and capitalized losses would not greatly exceed the cost of 6,600-volt motors and control. However, it is possible that the increased complexity of the system would more than offset any slight gain in the quality of motors, insofar as over-all reliability is concerned.

For a system employing 13,800 volts it would appear that the most economical application calls for operation of all synchronous motors above 800 horsepower at 13,200 volts. However, it is not considered possible to design a synchronous motor of less than 2,000 horsepower for operation at 13,200 volts, without reduction of safety factor. It appears advisable therefore to operate synchronous motors in the range of 800–2,000 horsepower at 2,300 volts. Since it is desirable to limit motors on the 575-volt system to approximately 500 horsepower in order to avoid heavy current starting equipment and

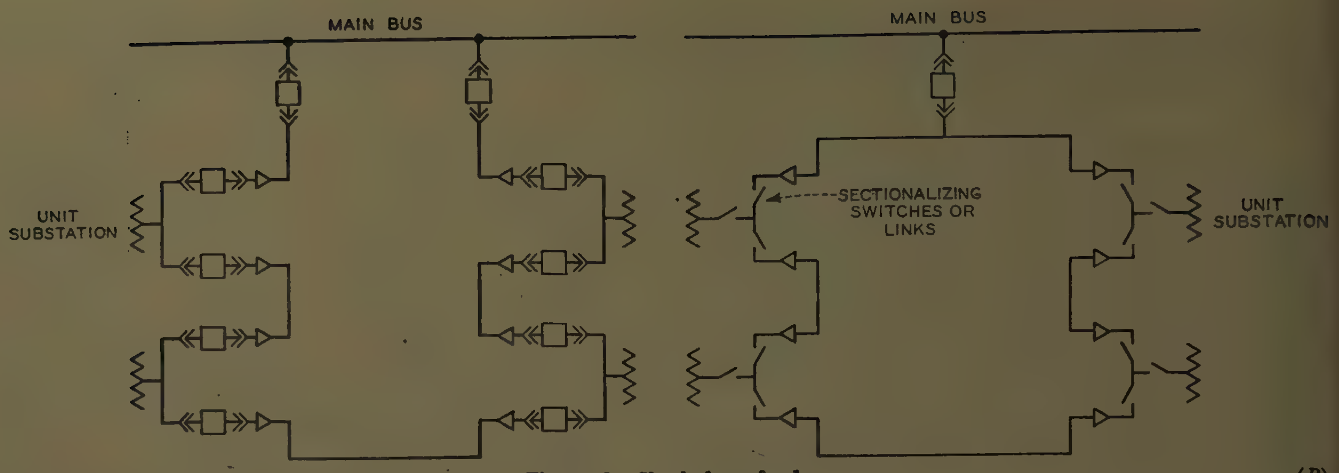


Figure 3. Single loop feeders

excessive cable size, it is reasonable to extend the limit for 2,300-volt motors down to 500 horsepower. Where there are only one or two motors in this range and they are between 500 and 700 horsepower they most likely should be operated at 550 volts. Above 2,000 horsepower motors may be operated directly on the 13,800 volt system, in most cases.

MAIN DISTRIBUTION FEEDERS

Generally speaking, high-voltage feeders are simple radial feeders; but frequently it is proposed to arrange the high-voltage feeders serving the load center distribution system in some more complex manner in an effort to improve the reliability of the low-voltage system. Considerable variation is possible in the layout of the feeders. The choice of feeder arrangement must be a balance between the desired reliability and the installed cost of the system.

The main alternative feeder arrangements can be listed in the order of increasing reliability and cost as follows:

1. Single radial feeders to groups of load center unit substations.
2. Single loop feeders with sectionalizing switches or links for groups of load center unit substations.
3. Parallel radial feeders with provision in each load center unit substation for switching to either feeder.

The single radial feeder (Figure 2) is the least expensive, particularly in the case where all load center units may be served by one feeder. However, the number of load center units per feeder is limited by the code requirements.

The loop system (Figure 3*A*) wherein the feeder forms a closed loop or ring main, offers some advantage over the single radial where some means of sectionalizing is provided on both sides of each load center unit. Thus when a faulty section of cable is located, this section may be disconnected until a convenient time to effect repairs. In the meantime, all units may be fed temporarily in two separate groups from the loop feeder circuit breaker. The advantage to be gained by this arrangement is debatable. In practice, all units connected to the loop would be shut down for an extended period if the fault could not be located readily.

If the loop is provided with automatic sectionalizing circuit breakers and adequate relaying, the loop cost is usually out of proportion to the advantages obtained. If, on the other hand, the loop is provided only with sectionalizing switches or links (Figure 3*B*), the gain in system reliability over the single radial feeder is very small and the operation of the system is hazardous unless some means is provided to interlock the switches with the loop circuit breaker.

The parallel radial feeder system (Figure 4), provides duplicate feeders to each unit substation and each feeder has a feeder circuit breaker. Some switching means is provided at each substation for connecting the substation to either feeder as desired. Of the total substation capacity connected to each pair of parallel feeders, normally half is connected to each feeder, but each feeder cable has sufficient capacity to serve all the substations in the event of a cable failure. This feeder arrangement is usually no more costly than the loop, and in contrast to the loop with automatic sectionalization it may be lower in cost.

A breakdown of time lost due to shutdowns in two typical pulp and paper mills equipped with radial distribution systems which have been in service for many years shows that the percentage of time lost due to failure of the electric distribution system alone (not including failure of motors and control) averages about three per cent. It is evident that a theoretically perfect distribution system would reduce the total plant shutdown by something less than three per cent. Since such arrangements as loop feeders and parallel feeders are far from perfect it seems to be evident that such arrangements actually will not be of significant benefit when viewed from the basis of over-all plant shutdown. Consequently, it may be stated that the additional cost of loop or parallel feeders very seldom can be justified.

CABLE SELECTION

A pulp and paper mill usually does not present any difficult cable application problems. While the atmosphere tends to somewhat higher humidity than in most industrial establishments, this is taken care of readily by the use of cable with a moisture protective jacket.

Selection of the correct cable for any circuit involves consideration of maximum load current, ambient temperature, and method of installation. Published cable data books translate this information into size of cable required on a normal thermal basis. Voltage drop is rarely a consideration in high-voltage feeders.

The size of cable also should be such that the insulation will not be damaged due to temperature rise resulting from the flow of fault currents. This consideration is overlooked frequently. High-voltage circuits usually are protected by standard 8-cycle circuit breakers so that the duration of fault current is greater than on low-voltage circuits protected by fuses or air circuit breakers. Data on short-time ratings of cables are available from the cable manufacturers.

Solid-insulation types of cable have been developed for 4,160-volt service and they are well adapted to pulp and paper mill service. One of such cables is a synthetic-rubber-insulated type, which is rugged and highly resistant to aging. This type of cable is quite economical in single-conductor types and is a logical choice for 4,160-volt installations. An additional advantage of this type of cable is that potheads for cable termination are not necessary.

When 4,160-volt cable circuits terminate in circuits which are exposed to lightning surges or switching surges and are protected by lightning arresters, varnished cambric cable should be used in place of rubber-insulated types. The impulse strength of rubber-insulated types of cable is not high enough to co-ordinate with standard lightning arresters.

While solid-insulation types of cable are available for 6,900-volt service, it is desirable to use either paper-insulated or varnished-cambric-insulated types due to their superior resistance to corona discharge. These cables of course would be lead-covered, and as lead-covered types are not economical in single-conductor cables, 3-conductor cable should be used at this voltage.

At this voltage the relative costs of paper-insulated and varnished-cambric-insulated lead-covered cables are quite comparable. Varnished cambric has some advantage in that it is better able to withstand normal stresses, and shorter radius bends. It also requires less care in splicing. This may not be of great importance in the initial installation for a properly installed system should have a minimum of spliced joints. However, it may be a factor in speeding up maintenance and system modification, and for some installations, splicing of paper-insulated cable may be beyond the capabilities of the maintenance staff.

As at 6,900 volts, both types are recommended for this voltage, in 3-conductor cable. While paper-insulated cable still suffers from the slight disadvantage of requiring more care in handling, at this voltage there is a considerable saving in the application of paper-insulated cable which usually offsets the disadvantage. Paper-insulated lead-covered 3-conductor cable results in a lower cost system at this voltage, based on Canadian prices.

There are several possible methods of installing high-voltage cables, only one of which could be called undesirable. Installation of high-voltage cables under the floor makes any installation inflexible, very costly, and makes the cables somewhat inaccessible for inspection and repair. Also, in a pulp and paper mill where wet floor conditions are prevalent, installation of cables under the floor should be discouraged. The most common method of installing cables has been the cable-in-conduit method. However, this is a costly arrangement and to some extent suffers the same drawback as the underfloor installation; that is, inflexibility and poor access for inspection and repair. While the conduit provides ideal protection for the cable it is much greater protection than is warranted in many cases. Either special rubber-jacketed or lead-covered cable may be installed on open racks of various types supported from the ceiling.

In some cases open rack mounting of lead-covered cables may not be considered to provide adequate protection for the cable. In this case, interlocked armor cables are available. These are standard varnished cambric lead-covered or synthetic-insulated cables over which is placed an interlocked steel, copper, or bronze armor.

SURGE PROTECTION

In connection with the high-voltage distribution system of a paper mill due consideration should be given to the question of adequate protection against lightning and switching surges. All exposed high-voltage feeder circuits should be provided with lightning arresters. Where power is taken from the utility through a step-down transformer bank, this bank probably will have lightning arresters on the high voltage side. Particularly in groundwood mills where a number of large grinder motors may be connected to a bus close to and at the same voltage as

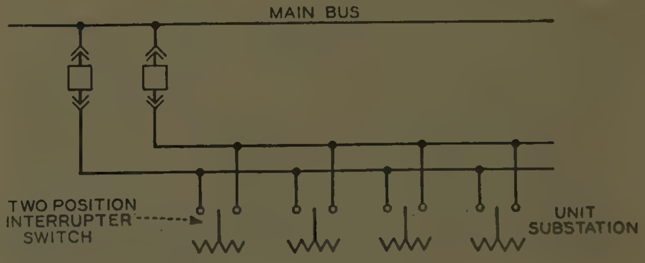


Figure 4. Parallel primary feeders

the secondary winding of the main bank, further protection on this bus is advisable. A rotating machine cannot be insulated readily to the same impulse level as a transformer, and when an unexcited motor is connected to the line transient overvoltages are produced which unduly stress the motor windings. The protection recommended is to connect protective capacitors and special station-type lightning arresters to the motor bus. The capacitor slopes the wave front of the surge and the arrester reduces the amplitude.

SYSTEM GROUNDING

Whether or not the high-voltage system in a paper mill should be grounded is a subject on which there can be endless argument. The advocates of the ungrounded system have one main argument against grounding; namely, that on the occurrence of a ground on part of a grounded system, the affected feeder is tripped automatically, thus shutting down its connected load. They contend that with the system left ungrounded but possibly equipped with some form of ground detector, no loads would be lost and the system could be operated until a convenient time such as the weekend. The majority of the older paper mill distribution systems are at the present time operated ungrounded.

There are, however, advantages in grounding the system which outweigh the disadvantages. It is true that with isolated neutral and some form of ground detection, the system can be operated with a single ground. However, most ungrounded systems today are operating without ground detection or, due to the tediousness of checking each feeder in turn to locate the ground, this location and repair is not done at the first opportunity, and in fact nothing is done until a second ground occurs, which shuts down two feeders instead of one. This, however, is not the most serious disadvantage of an isolated neutral system. With such a system, not only will the occurrence of a ground on one phase overstress the windings of all connected machines as long as the ground is on, but switching surges and arcing grounds can produce serious overvoltages up to the order of six times normal. Thus flashovers can and often do occur at unexpected locations quite remote from the point of original fault.

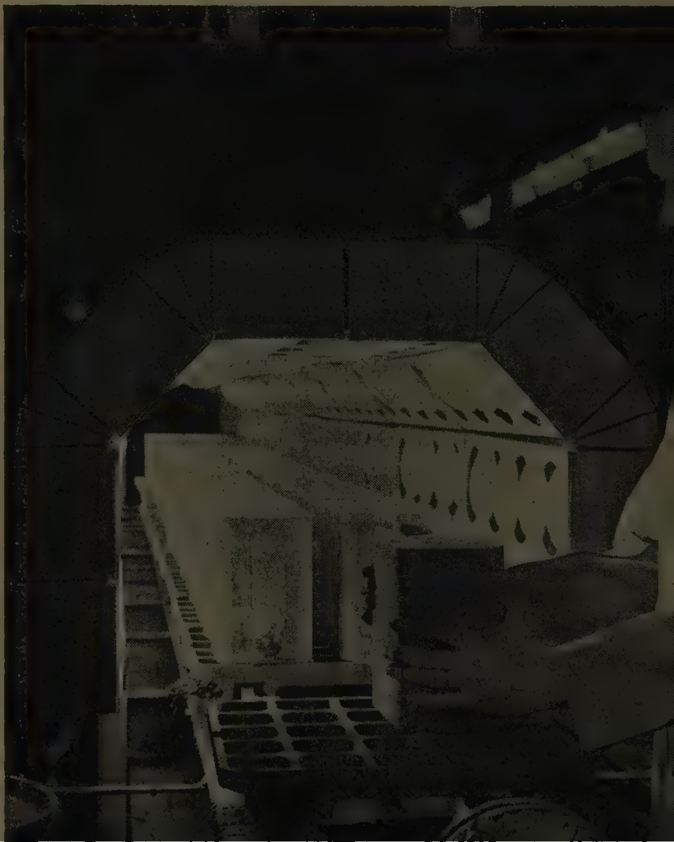
With a grounded system overvoltages are reduced to a safe value and automatic selective indication of ground faults in feeder circuits is obtained. Analysis of shutdowns in a typical paper mill shows that such a very small percentage is due to the electric system, the tripping of a feeder due to ground fault at the time of fault will not affect seriously the mill efficiency and is preferable to risking the more widespread and serious trouble possible with the ungrounded system.

The method of grounding requires careful consideration. Grounding can be either solid or through reactance or resistance, and the ground connection can be made at one or more locations on the system. Grounding solidly without intervening impedance means high ground currents with resultant severe damage to equipment through which the ground current flows, while grounding at more than one point leads to relaying difficulties. Thus the preferable grounding method is through a resistance which will limit the ground current to a value consistent with minimum relaying requirements which ranges from 500 to 1,000 amperes. The number of grounding points should be limited to one on each part of the system fed by a separate transformer bank or bank of generators on a common bus.

The ground point may be the neutral point of the transformer bank if the transformer secondary is Y-connected, it may be the neutral of one of the large Y-connected grinder motors, or it may be the neutral point of one of a number of generators connected to the bus. If no Y-connected transformer or machine winding is available, use must be made of a special zigzag grounding transformer.

Precision Casting

Replacing steam tables, low temperature ovens, and hot plates, banks of 250-watt infrared lamps (248 in all) are used to dry the molds and melt out 98 per cent of the wax pattern at the precision "lost-wax" casting foundry of the Westinghouse Electric Corporation. The balance of the wax is burned in the preheat furnace where molds are heated to 1,000 degrees centigrade for casting. The new process is said to reduce mold cracking



Control of Electric Boilers

M. EATON
MEMBER AIEE

Automatic process control and the design of control instruments are developed to such an extent that few continuous processes now are controlled manually. The electric boiler application has lagged behind mainly because instruments must be supplemented with specially arranged equipment as part of the controlling means.

SCIENTISTS predict that within 20 years many central stations will operate on atomic energy. The cost of fissionable material has little bearing on the cost of atomic power and consequently such plants will resemble hydroelectric plants with unlimited water storage. This will broaden the field for electrical steam generation with surplus generating capacity, that now is restricted mainly to districts wholly supplied by hydroelectric power.

Electric boilers of the water-resistance type were introduced in Canada after World War I for the purpose of utilizing surplus hydroelectric power. Since then about 200 units have been installed with an aggregate capacity of approximately 2,000,000 kw. There are a few installations in the United States aggregating about 100,000 kw. European installations amount to nearly 1,000,000 kw, about half of which are in Norway. Most of these boilers are operated manually, and although satisfactory operation can be obtained with manual regulation the need of precise automatic control long has been recognized.

CHOICE OF CONTROL

The amount of stabilizing action required in control is proportional to $(A+B)/C$ where A, B, and C are the process, controller, and capacity lags respectively. The capacity lag usually is the determining factor and when it is large compared with the other two a simple 2-position controller may be adequate.

Proportional control, which maintains a linear relation between the position of the final control element and the deviation of the controlled variable from the set point, is satisfactory with moderate lags. If a low sensitivity adjustment is required for stable operation, an objectional amount of offset (the difference in value of the controlled variable corresponding with the set point and the rate at which the control agent is supplied) may result unless reset control action is provided. Reset action increases the sensitivity of an automatic controller, following a change in control agent demand, for the purpose of overcoming offset. Proportional control plus reset is similar in effect to proportional-speed-floating control, which varies the position of the final control element at a rate proportional to the magnitude of deviation of the controlled variable from the control point.

If the capacity lag is small compared with the other lags, and large changes in demand for control agent occur, proportional-speed-floating plus preset controller action is required. Preset action is used to mean controller action that alters the position of the final control element an amount corresponding with the rate of change in the value of the controlled variable.

AIR-OPERATED CONTROLLERS

Figure 1 shows a typical control process used to regulate the temperature of water taken from a storage tank. The thermometer bulb, a Bourdon tube in the instrument, interconnecting tubing, and the liquid or gas they contain constitute the elements which, working together, regulate the controller and position the control valve accordingly. The valve is the final control element regulating the flow of control agent, which in this instance is steam. Steam is the medium required to maintain the temperature (controlled variable) within limits.

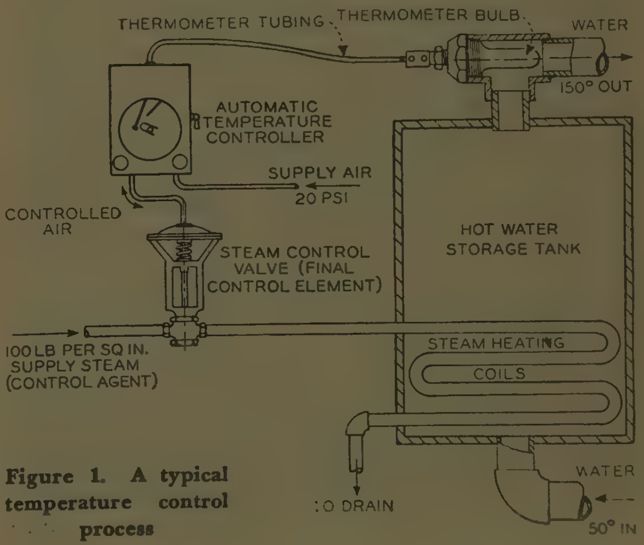


Figure 1. A typical temperature control process

Essential substance of paper 47-129, "Automatic Operation of Electric Boilers," presented at the AIEE summer general meeting, Montreal, Quebec, Canada, June 9–13, 1947, and scheduled for publication in AIEE *TRANSACTIONS*, volume 66, 1947.

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The capacity lag is determined by the size of the storage tank as compared with the demand for hot water. The process lag includes the time it takes to transfer heat from the steam to the water, plus the time required for a change in temperature at the thermometer bulb resulting from a change in temperature at the heating coils. The controller lag is the time required to effect a change in the position (opening) of the control valve corresponding with a change in the temperature of the water at the thermometer bulb.

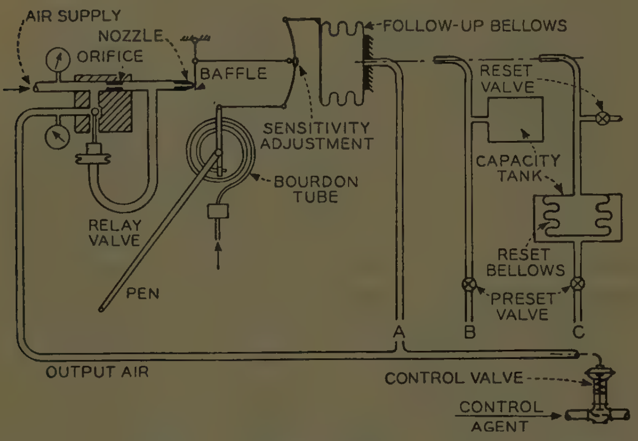

Figure 2. Schematic diagram showing alternate essential elements

A—Proportional controller
B—Proportional controller with preset action
C—Proportional controller with preset and reset action

If the storage tank is quite large compared with the demand for hot water, 2-position controller action is adequate. Moderate storage capacity requires proportional controller action for control stability, and if it is desired to maintain the control point close to the set point reset action is necessary. If the storage tank is small, with fluctuating demand, then proportional plus preset plus reset controller action is required.

Figure 2*A* represents a proportional controller (direct acting). As the value of the controlled variable rises, the pen turns in a clockwise direction, and through interconnected linkages the lower end of the baffle is moved to the right. This reduces resistance to air flow through the nozzle, thus decreasing the back pressure and causing the relay valve to increase its opening. Rising output air pressure decreases the opening of the direct-acting control valve. As the output air pressure rises, the follow-up bellows moves the top of the baffle to the left an amount depending on the sensitivity adjustment. This action partly offsets the initial movement of the baffle away from the nozzle and has the effect of causing the control point to follow the controlled variable thus providing means for sensitivity adjustment.

The capacity tank and preset valve shown in Figure 2*B* delay the follow-up action. The result is that in the event of a sudden change in the controlled variable a large initial movement of the control valve occurs in the direction to correct it. This effect depends on the rate of change in the magnitude of the controlled variable regardless of its actual value.

Figure 2*C* shows the essential elements of a controller having both preset and reset controller action. A rapid change in the value of the controlled variable results in an initial output air pressure change corresponding with high sensitivity adjustment. After a time delay, depending on the adjustment of the preset valve, the reset bellows transmits to the follow-up bellows a corresponding pressure change. The baffle position then is altered to reduce the change in output air pressure an amount depending on the sensitivity adjustment. This action is followed by a return to high sensitivity after a time interval depending on the adjustment of the reset valve. The optimum sensitivity, preset rate, and reset rate depend on the process lags and the magnitude of load changes. They are adjusted in service to the values at which the most stable operation is obtained.

ELECTRIC BOILER CONTROL

Figure 3 is a sectional view of a well-known electric boiler of the water-resistance type. Steam is raised by passing current through the water between electrodes. The water resistance is inversely proportional, and the power input is therefore directly proportional, to the electrode immersion, the temperature of the water, and its salt content, which increases as water is evaporated.

Electric boilers usually are regulated by maintaining the salt content within limits by bleeding and by varying the water level on the electrodes in accordance with the demand for steam. Power input is matched with steam demand to maintain constant pressure. The power input is the control agent supplying the heat energy required to generate steam, and the electrode immersion is the final control element.

The capacity lag is proportional to the steam storage capacity of the system under control. If the steam storage capacity is only that supplied by the electric boiler and steam mains, the capacity lag is small. The process lag includes the time required to heat the feed water to steam temperature and to evaporate it. Since the electrode immersion is the final control element the controller lag includes the time required to change the boiler water level. The process and controller lags are, therefore, large compared with the capacity lag. As the steam pressure and temperature rise, the water resistance falls with increased power input and accelerated rise in pressure. Conversely, as the steam pressure falls there is a reduction in power input when an increase is needed. For these reasons an electric boiler is difficult to regulate on fluctuating loads. Unless additional steam storage capacity is provided nothing less effective than the equivalent of proportional-speed-floating plus preset controller action will provide stable automatic control. This explains why early attempts to regulate electric boilers automatically were not entirely successful.

CONDUCTIVITY CONTROL

An electric boiler may be regulated either by maintaining the salt content within limits and varying the water level, or by holding the water level constant and varying the salt content or conductivity. When water conductivity is the final control element, controlling means is provided whereby the conductivity is increased by adding salt solution (soda ash) and decreased by bleeding. The salt solution control apparatus, by being made partly responsive to steam flow, anticipates the demand for salt solution and the bleed valve operates in two stages. The result is something a little more effective than 2-speed-floating control. Although the operation is much improved, as compared with manual control, some independent steam storage capacity is required for stable operation on fluctuating loads. There is also appreciable maintenance work necessary to keep the equipment in good working order, and an objectional loss in boiler efficiency results when frequent bleeding to drop load is necessary. Because of these defects it was decided to develop the water-level-type control.

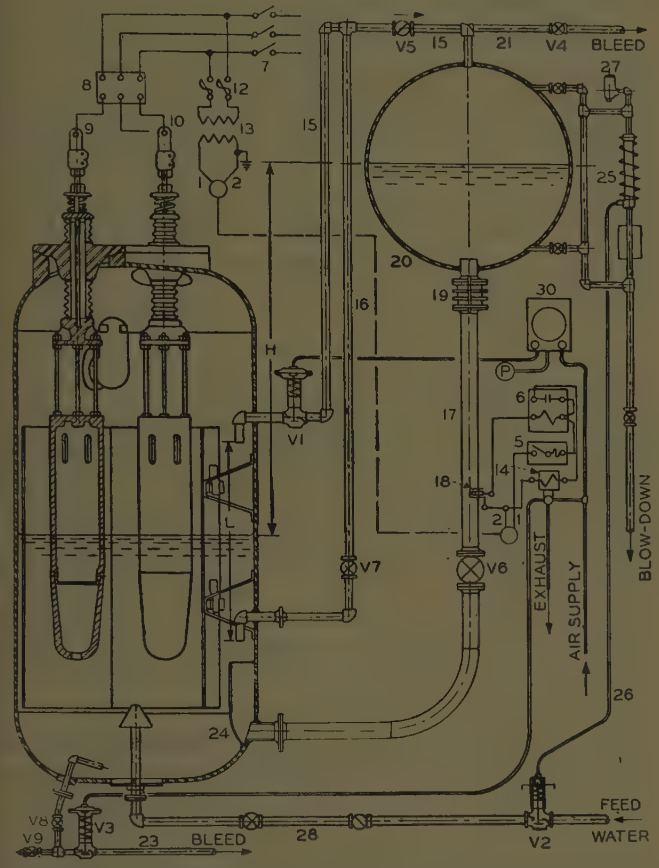

Figure 3. Sectional view of an electric boiler equipped with Eaton automatic control type WL

WATER-LEVEL CONTROL

The problem of developing water-level control was not only to provide controlling means with nearly all the stabilizing features known to the art, but to do so with apparatus that is simple and reliable. Three variables, steam pressure, the rate of feed water flow, and the boiler water salt content, are controlled independently but in such a way as to assist in maintaining control stability. An electric boiler with control apparatus is shown in Figure 3.

Pressure Control. Steam is bled through *V4* from control tank 20 to a feed-water heater, or low pressure system, at a constant rate. A diaphragm valve *V1*, responsive to a proportional controller 30, regulates the flow of steam from the boiler to the control tank in response to variations in the controlled pressure. The controller pressure connection *P* is made with either the boiler or the steam header.

If the controlled pressure rises above normal, controller 30 functions to decrease the opening of *V1*. Steam is discharged then from the control tank faster than it is replaced, resulting in transfer of water from the boiler to the control tank, decrease in power input, and return to normal pressure. *V1* increases its opening on falling pressure, allowing the control tank steam pressure to rise and water to be returned to the boiler by gravity, thus causing an increase in power input and return to normal pressure. This is proportional-speed-floating controller action.

The equipment shown in Figure 3 uses the Bergeron separate vessel self-regulating effect to obtain preset controller action. The steam space in the control tank and valve *V4* serve the purpose of the capacity tank and preset valve (Figure 2*B*). Check valve *V5* prevents boiler and control tank steam pressures being equalized by passage of steam through pipe 15 to the boiler.

Boiler Water Level Limits. If the boiler water level rises above the range indicated by *L*, access of steam to pipe 15 is cut off and water is transferred to the control tank by control action as previously described. If the level falls below *L*, steam rises through pipe 16, by-passing valve *V1*, and causing water to be returned from the control tank to the boiler. These water level limits are the extreme positions of the final control element. The boiler load corresponding with the water level depends on the boiler water bleed control point.

Bleed Control. When the conductivity of the water in pipe 17 rises above the control point, as determined by the setting of relay 6, the relay current reaches the value at which the contacts close to energize 3-way valve 14, and to open the air-operated bleed valve *V3*. As boiler water is bled off it is replaced by comparatively pure feed water thus reducing the salt content and conductivity to normal, at which relay 6 opens its contacts and valve *V3* recloses.

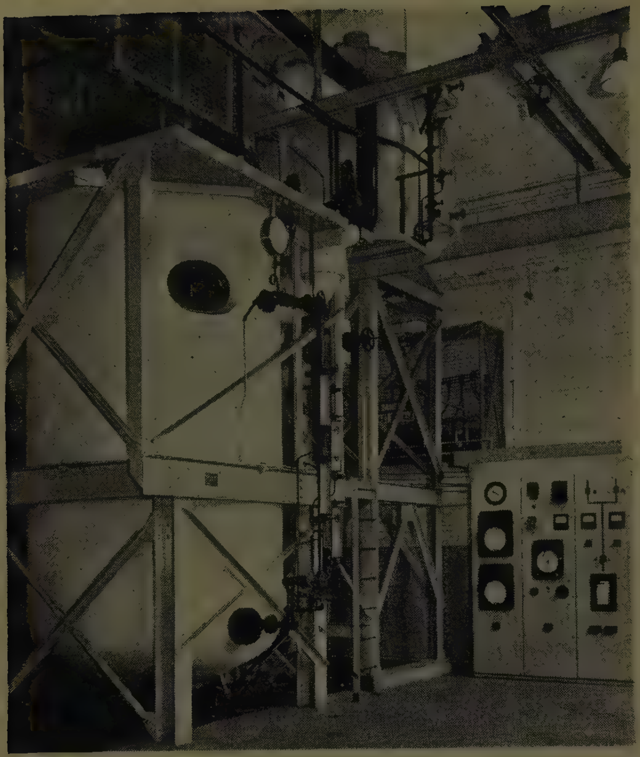

Figure 4. A 20,000-kw electric boiler with equipment as shown in Figure 3

The conductivity cell is located in pipe 17 in preference to the boiler shell because the passage of water through the pipe washes the electrodes and a desirable timing effect is obtained. The bleed control apparatus functions as a simple 2-position controller, which is satisfactory because of large capacity lag in salt concentration.

Feed Water Regulation. The control apparatus functions in such a way that all water admitted to the boiler, in excess of that required to maintain the operating water level, is transferred to the control tank which is maintained approximately half full, thus providing storage water for raising the level in the boiler and storage space for transfer of water from the boiler.

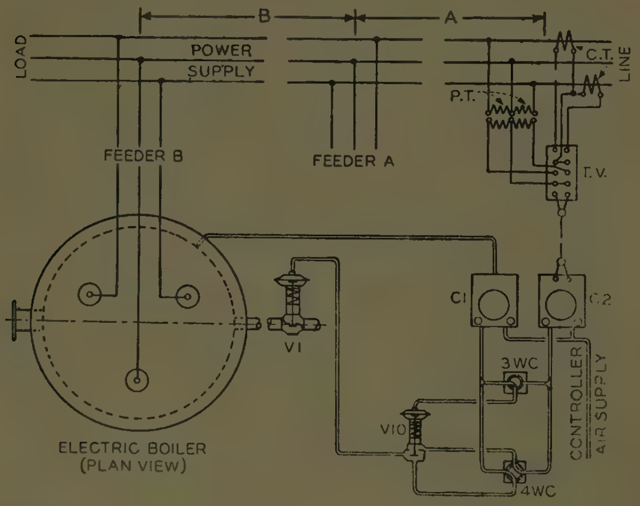

Figure 5. Modified instrumentation for alternative pressure and power control

The generator assembly 25 of a Bailey thermohydraulic feed water regulator is mounted vertically on the control tank as shown. The feed water flow to the boiler, through *V2*, is responsive to the water level in the control tank.

The application of reset or preset action to controller 30 would serve no useful purpose. Reset is unnecessary because the controlling means is inherently a floating type, and preset action would increase the opening of valve *V1* when check valve *V5* is functioning to prevent flow of steam through it. A valve positioner, which is a device used to amplify the controller output air pressure for precise positioning of the diaphragm valve, may be used to advantage when low sensitivity adjustment is desirable.

ALTERNATIVE PRESSURE AND POWER CONTROL

The amount of electric boiler or dump power that can be supplied from a hydroelectric system depends on the amount of surplus water and reserve generating capacity. Large electric boilers are operated frequently at limited power input for the purpose of maintaining a minimum system reserve. When these electric boilers are operated at fixed load, associated fuel-fired boilers supply the balance of steam required. The restriction in boiler load may be removed and the coal boilers shut down at off-peak times.

Figure 5 serves to describe modified instrumentation designed to obtain the maximum advantage of the automatic control when operating with the above load conditions. *C1* and *C2* must be reverse acting to obtain the desired controller action (a demand for higher steam pressure or increased power input, respectively, results in an increase in controller output air pressure and consequent increase in the opening of valve *V1*). With the boiler operating at constant load, as determined by the control point adjustment of potentiometer controller *C2*, and cocks *3WC* and *4WC* turned as indicated, the pressure control point of pressure controller *C1* is adjusted to a value about ten per cent higher than the steam pressure maintained by the coal-fired boilers. The output air pressure of *C1*, therefore, is high and diaphragm valve *V10* is positioned to put valve *V1* under control of the power controller *C2*, which maintains the boiler load at the desired value. If a sudden and substantial decrease in steam demand causes the pressure to rise above the control point of *C1* the output air pressure from this instrument falls, reversing the position of *V10* and thereby transferring the boiler to pressure control. Boiler load then is dropped to bring the steam pressure under control.

When operating on pressure control, cocks *3WC* and *4WC* are reversed, the control point of *C1* is adjusted to normal steam pressure, and that of *C2* is set at the desired maximum load. The control then becomes responsive to instrument *C1* and instrument *C2* provides load limit adjustment that otherwise would be determined only by the upper limit of water level on the electrodes of the boiler.

AUTOMATIC CONTROL ADVANTAGES

Some advantages of automatic as compared with manual control are as follows:

1. Operating efficiency may be increased by eliminating, or reducing to a minimum, avoidable losses such as bleeding to drop load, loss of steam through the safety valves, and excessive bleeding on light load. If the load is fairly steady and over 25 per cent of the boiler rating no gain in efficiency is possible with automatic control, however, on fluctuating or light loads the improvement might be as much as five per cent.

2. Both the controlled pressure and the power input are held within closer limits than is possible with manual control.

3. Improvement in control stability reduces instantaneous peak loads and thereby increases the average load that can be taken.

4. Electrode corrosion is decreased.

5. Small boilers may be operated unattended.

6. Instrumentation may be modified to obtain control effects that would not be practicable with manual regulation.

The installed cost of automatic control is approximately five per cent of the complete electric boiler installation including power transformers.

The Utility View of Electric Boilers

L. B. STIRLING
ASSOCIATE AIEE

The installation of electric boilers to provide off-peak loads for hydroelectric utility systems is now widely accepted in Canada. Such installations have proved to be beneficial to utilities, customers, and to the nation in general.

HYDROELECTRIC utility systems encounter periods during which there is energy available in excess of primary contract loads, and which cannot be stored for future use. This situation may arise from seasonal or irregular run off, unexpected reduction in load demand, or a general business recession. Under certain circumstances it may be possible to dispose of this excess energy to other interconnected power systems, but where there are no such interconnections, or other available load, the surplus energy must be wasted by spilling water through the flood channels of the generating stations. When it is possible to convert this energy to electric power with existing equipment, it becomes practically a by-product and can be sold profitably at a price which represents its value to the consumer.

The electric boiler or electric steam generator, as it sometimes is called, provides a ready means of converting electric energy into steam at the point of use. Many large Canadian manufacturing industries, the greatest of which is the pulp and paper industry, consume large quantities of process steam in their operation. This generally is produced by means of coal-fired boilers and accounts for an appreciable part of the cost of the finished product. This steam is required principally for heating and saturated steam is quite satisfactory for this purpose. The steam produced by an electric boiler is of approximately this quality, and its suitability for this application is indicated by the continued demand of a diversity of manufacturers for further installations of electric boilers of all sizes.

POWER CONTRACTS

Contracts covering the supply of electric energy for steam generation usually stipulate that the delivery of power at any particular time and in any specific quantity is not guaranteed. Furthermore, it is stated that the supply may be interrupted or restricted at any time. These conditions are essential in view of the fluctuating supply of surplus power and the necessity of maintaining a reserve for prime contract requirements, but most utilities make every effort to avoid inconveniencing

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Essentially full text of a conference paper, "Electric Boilers From the Utility Point of View," presented at the AIEE summer general meeting, Montreal, Quebec, Canada, June 9–13, 1947.

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their customers by unforeseen interruptions. The usual practice is to furnish each electric boiler customer with a yearly estimate of the energy which he will receive and the periods in which it will be available. It is not unusual to stipulate that most of this energy shall be taken at night with the electric boilers operating at reduced load or shut down during the day time. Such a schedule presents no difficulty as regards the operation of these boilers since their output is controlled readily and can be adjusted quickly to meet any alternations in steam demand or power supply. This estimate is revised at intervals and permits the customer to order whatever fuel he may need to meet his annual steam requirements. When the generating or transmission capacity of the system is reduced suddenly by the failure of some piece of equipment, it is frequently possible to make a temporary reduction of electrochemical furnace load for a sufficient length of time to permit the customers to transfer their steam load to their fuel-fired plants.

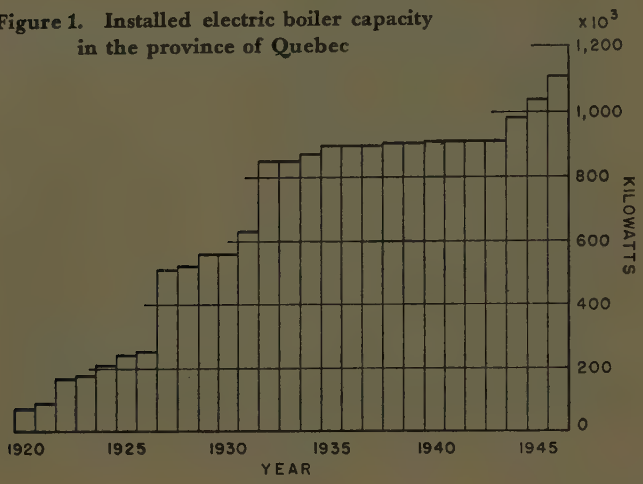


Figure 1. Installed electric boiler capacity in the province of Quebec

COST OF INSTALLATION

One kilowatt-hour of energy will generate 3.1 pounds of steam, and the production cost of steam from a modern coal-burning plant in the province of Quebec is 50 cents per 1,000 pounds. The value to the customer of such electric energy is accordingly about 1.5 mils per kilowatt-hour. This figure represents gross revenue and must be reduced by the cost of transmission losses, fixed charges on the installation, maintenance, and other costs. As the customer must provide a fuel-burning plant of sufficient capacity to meet his total requirements, in order to insure the continuity of his operations, he seldom feels justified in financing the installation of an electric boiler. The average cost of such an installation is five dollars per kilowatt of capacity but varies widely in accordance with the size of the installation and the location of the customer. Very frequently the installation is financed by the electric utility which retains possession of the equipment, even though it is located on the customer's premises. The customer operates and maintains the boiler but the utility may make some allowance towards the cost of maintenance. Occasionally the customer provides the equipment or else he may acquire the equipment over a period of time.

DESIGN OF ELECTRIC BOILERS

There are two distinct types of electric boilers, each of which has a fairly well-defined field of application. In the immersion heater type, the heat is produced by standard heating units installed in a pressure shell of suitable size. Such an electric boiler is simple to build and is economical and easily controlled in the smaller sizes. Standard models are available in capacities up to 500 kw at 500 volts, but for larger capacities, the cost of the heaters and control equipment becomes excessive. It is generally preferable to employ the electrode type of boiler for loads in excess of this figure.

While there are several varieties of the electrode-type boilers, the principle of operation is similar and consists of utilizing the electrical resistance of the water to be evaporated as the medium for generating the required heat. In a typical arrangement of this class of electric boiler, current is made to flow between an insulated electrode and a plate connected to the pressure shell and the power consumed in the water path vaporizes the water directly, thus avoiding all losses as a result of heat transfer.

The water in the electric boiler must have a considerably higher conductivity than that of the feed water in order to obtain good boiler efficiency. This higher conductivity results naturally from the concentration of the salts which are introduced with the feed water, but when necessary it is accelerated by the injection of soda ash. There is, however, a maximum desirable conductivity which, if exceeded, will result in operating and maintenance troubles, and it is accordingly necessary to bleed off a small amount of water at regular intervals to maintain the desired concentration. This bleed represents a definite loss of heat and accordingly should be kept to a minimum in order to maintain a high operating efficiency. The amount of bleed should not exceed 20 per cent of the feed but the more usual proportion is of the order of 5 per cent.

There are two conflicting conditions to be met in the design of an electric boiler. As explained in the preceding paragraph, it is desirable to maintain the water concentration and consequently the conductivity at a relatively high value but it is essential to hold the average current density on the electrodes down to a low figure in order to avoid excessive depreciation of the boiler. A practical compromise consists of limiting the water resistivity to 600 ohms per inch cube and limiting the current density to a maximum of 1.25 amperes per square inch.

MAINTENANCE OF BOILERS

It is now practical to build a single-shell 3-phase boiler with a capacity of 40,000 kw. There are, however, certain components of electric boilers which deteriorate with use, and the design and maintenance of such components have been improved steadily as a result of experience obtained from the operation of numerous boilers.

There is a tendency in electric boilers for the current to concentrate towards the tips of the electrodes. This is caused by the shape of the electric circuit in the boiler and by the blanketing effect of the steam on the upper part of the electrodes. Under severe conditions, such as are caused by operation at low water levels, this effect may be aggravated to an extent which results in arcing at the end of the electrodes which causes rapid burning of the electrode metal. With careful operation, however, the electrodes will last for four or five years and can be reconditioned for a further term by cutting off the worn tips and replacing them with new castings. Recent models of electric boilers have been built with the electrode tip as a separate piece in order to facilitate the tip's replacement when it is necessary to do so.

Electrode bushings are subjected to heavy mechanical and thermal stresses and occasionally fail by cracking. The internal or steam bushing also is exposed to the action of live steam which reduces ordinary electrical porcelain to a soft chalky material. The life of a porcelain steam bushing is seldom over one year under normal conditions but steatite bushings, manufactured in England, have been found to have twice the life of porcelain. Prior to the war, a special type of bushing was imported from Germany which was much superior to any other type, but it has not yet become available in Canada.

PROTECTION OF PRESSURE SHELL

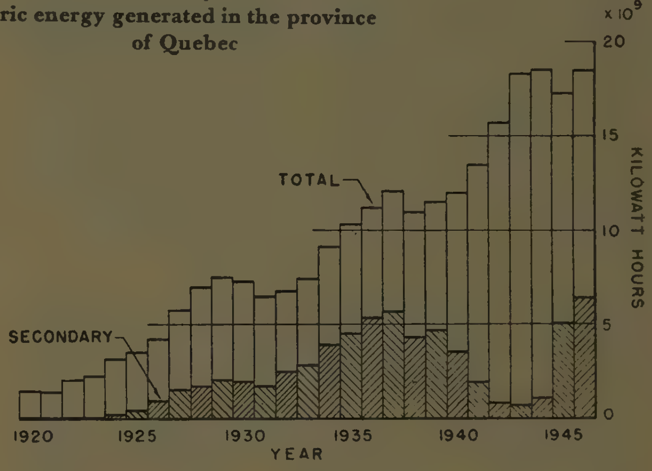
A false shell is provided to protect the pressure shell from electrolysis. In the course of four or five years it may become unserviceable and can be replaced readily. In some boilers it can be removed and reinstalled as a unit, but in the larger ones it is assembled in sections and welded together in place. The false shell is made of light steel plate which gives a satisfactory life and is not difficult to handle while assembling it inside the pressure shell.

There is very little deterioration of the pressure shell and many boilers still in operation have been in service for over 20 years. Those parts requiring replacement at regular intervals are relatively inexpensive and easily installed so that the average maintenance costs of these boilers are comparatively low.

ECONOMICS OF OPERATION

The use of electric boilers is by no means a new development as such boilers have been in use in Canada for at least 30 years. That they have been beneficial to both the utilities and the customers is proved by the regular increase of installed capacity, as shown for the province of Quebec in Figure 2. The proportion of electric energy consumed in the production of steam is illustrated graphically in Figure 2, and it will be appreciated that the revenue from this source may form a considerable part of the income of the utilities. It also represents a saving of thousands of tons of coal which is a very desirable factor in the economy of a country whose coal deposits are as limited as those of Canada.

Figure 2. Secondary and total electric energy generated in the province of Quebec



CONCLUSIONS

During the period in which electric boilers have been in general use, Canada has experienced a wide range of operating and economic conditions. This has resulted in the definite establishment of the following conclusions:

1. Electric boilers provide a satisfactory means of disposing of surplus hydroelectric energy which gives a reasonable return on the additional investment in them.
2. They can provide an initial load for additions to hydroelectric developments which may be built in anticipation of future prime load demands.
3. Their reliability, convenience, and economy have proved satisfactory to the customer.
4. They accomplish a saving of natural resources which is beneficial to the national economy.

There is no doubt but that the use of electric boilers is established firmly in the industrialized sections of Canada. The number of installations undoubtedly will increase with the further development of water power resources necessary for the growing power demands of Canada.

Low-Voltage Power Distribution

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The load center method of distribution offers many advantages when compared with the old type of distribution by long heavy conductor feeders from a single large substation. Because of the excellent reliability of electric equipment and distribution systems, a straight radial power distribution system is all that usually is warranted.

PRIOR to about 1941, there had been no major advance in power distribution systems for industrial plants except for the introduction of metal-clad switchgear and noninflammable liquid-insulated transformers. Power systems were studied individually, and in most cases without proper evaluation of all components, and there were very few attempts to study basic patterns. There were no general guides available to show the best way of doing the majority of the jobs which had similar over-all requirements.

About 1941 a new approach was taken in studying industrial power systems which resulted in the so-called load center principle of distribution. There are two fundamentals associated with the load center principle of distribution; power is distributed at high voltage to the load center where it is stepped down to utilization voltage and distributed to the load by short low-voltage feeders; and where the total load exceeds about 500 to 1,500 kva, several unit substations are used rather than a single large substation with each substation located near the center of its load area.

The old method, which is referred to here only by way of contrast, employs a large substation in which large blocks of power are transformed from high voltage to low voltage in one area and then the power distributed to the load areas by long heavy-conductor feeders.

In comparing the over-all economics of the load center and the old method of power distribution, the only true comparison is on an installed basis and including all components, such as the primary switchgear, primary cable, transformers, low-voltage switchgear, and low-voltage cable. Unless all of these are evaluated properly, erroneous comparisons will result, for example:

1. Transformer costs, in dollars per kilovolt-ampere, decrease as the transformer rating increases, thereby tending to favor large transformer units.

2. However, as the transformer rating increases, the fault duty on the low-voltage bus increases, requiring larger and more costly breakers. Therefore, the cost of low-voltage switching of equipment favors small transformer units.

The optimum size of substation, considering all of the afore-mentioned variables and contradictory trends, is shown in Figure 1. It should be noted that for 460-volt systems the optimum size of substation ranges from 500 to 1,500 kilovolt-amperes, which is much smaller than was considered economical previously. Although these data are based on a load density of 10 volt-amperes per square foot of plant floor area, the optimum size substation for other load densities ranging from 3 to 30 volt-amperes per square foot still comes within this same general range. These data also apply to 575-volt systems.

The 460-volt system is common in the United States and the 575-volt system in Canada. Even though the 575-volt system is slightly more economical than the 460-volt system, there are very good reasons for retaining the 460-volt system for United States practice; the main reason is the greater availability of 440-volt utilization equipment. There are very few new 575-volt installations except as an extension of existing systems and then mainly for interchangeability of equipment. Also, some mills are changing from 575-volt to 460-volt systems, whenever practical, because of the greater availability of 440-volt utilization equipment.

Cost data from reliable contractors and plant engineers show that the installed cost of the entire distribution facilities with the load center system including unit-type substation equipment is 15 to 30 per cent less than for the old method of distribution. The load center system is applicable to all sizes of paper mills where a transformation of voltage is required.

LOW-VOLTAGE UNIT SUBSTATIONS

The load center unit substation was introduced as a necessary counterpart of the load center principle of distribution. A unit substation combines the functions of transformation and low-voltage circuit protection in a compact factory-assembled unit equipment having the features of safety (the low-voltage switchgear is metal-enclosed and the switching devices are of

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Essential substance of a conference paper, "Power Distribution Systems for Pulp and Paper Mills—Low-Voltage Systems," presented at the AIEE summer general meeting, Montreal, Quebec, Canada, June 9–13, 1947.

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adequate interrupting rating), simplicity, and ease of installation. Installation costs of unit-type equipment range from 15 to 30 per cent less than the on-the-job assembly of components. The load center system with unit substations is particularly adaptable for load expansion; as the load increases and exceeds a given substation capacity, additional unit substations can be added near the load area.

Unit-type motor control substations are used when it is desirable to have the motor starters centrally located. These substations combine the functions of transformation and motor control in a single convenient equipment and have the same general construction and safety features as the load center unit substations. D-c power requirements can be met by means of a d-c unit substation, which includes a sealed-ignitron mercury-arc rectifier equipment, transformer, and switchgear. Transformers for these unit substations may be oil- or noninflammable-liquid-filled, or of the air-cooled dry type.

The following is a summary of the advantages of the load center principle of power distribution with unit substation equipments:

1. Lower installed cost of the entire power system.
2. Easier to install.
3. Adaptable to future expansion. Unit substations can be added as the load increases; it is not necessary to invest extra capital in substations larger than necessary in anticipation of some future increase in load.
4. Voltage regulation is excellent because of short secondary feeders.
5. Less engineering required.
6. Lower system copper losses.
7. Higher salvage value.

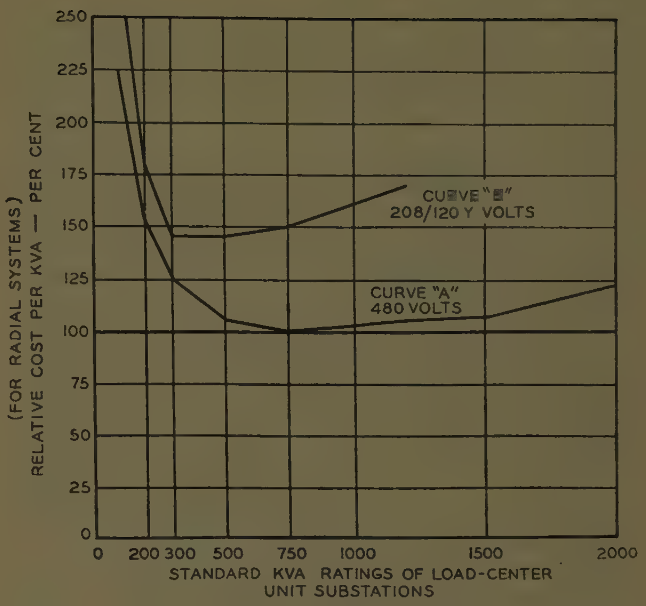
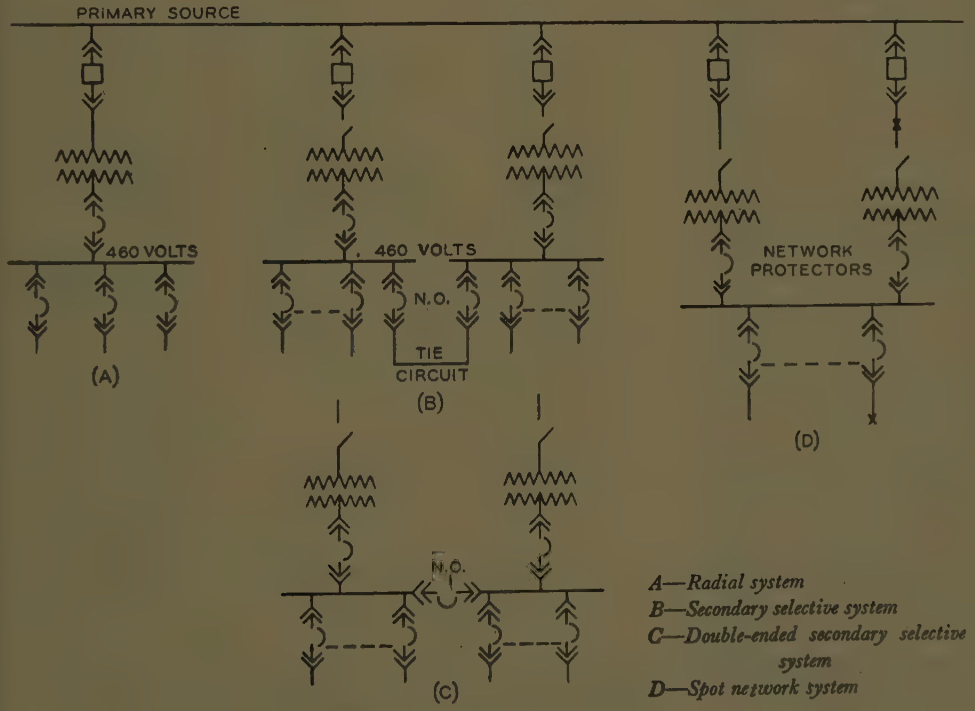


Figure 1. Relative costs of load center systems in terms of unit substation rating

UNIT SUBSTATION LOCATION

In order to obtain the minimum investment for the secondary distribution system, the unit substations should be located as near the load center as possible. Therefore, it is important when planning new mills or expansions to allow space for the unit substations in the load areas, and this space requirement is relatively small. Unit substations do not necessarily have to be on the main floor area; they may be in a basement or on a balcony.



A—Radial system
B—Secondary selective system
C—Double-ended secondary selective system
D—Spot network system

Figure 2. Circuit arrangements

In sulphite and sulphate mills having corrosive atmospheric conditions, it is very desirable to locate substations, motor controls, small motor generator sets, and other electric equipment in enclosed and ventilated rooms. The trend in mill design, and especially for bleaching plants, is to provide separate rooms for the electric equipment. This permits the use of standard equipment and also reduces maintenance costs. When equipment is exposed directly to acid and alkali, it

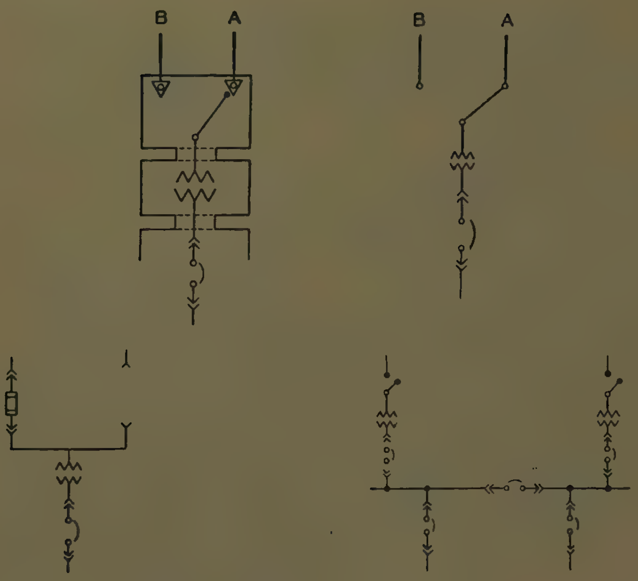


Figure 3. Primary selective system

is necessary for equipment to have a special paint or lacquer finish, coating or plating of various electric parts, and totally enclosed motors, all of which increases the cost. Maintenance of electric equipment directly exposed to acid and alkali conditions is much higher than similar equipment in a properly ventilated room. Where it is not possible to provide separate enclosed rooms in those atmospheric conditions the outdoor-type substation equipment is used.

SYSTEM ARRANGEMENTS

The small amount of time lost due to various electrical causes in Canadian paper mills as mentioned in "High-Voltage Distribution Systems," a companion article appearing on pages 985–90 of this issue, is a tribute to the high reliability of electric equipment and power distribution systems. This may be interpreted to indicate that a straight radial power distribution system is all that is warranted generally; of course, there are certain power loads which should have a greater reliability such as boiler house auxiliaries.

An examination of many existing and proposed large low-voltage distribution systems in both Canadian and United States mills shows that they seldom employ a straight radial system, but generally a modification of the secondary-selective or primary-selective arrangement. This indicates that these mills require more than a straight radial low-voltage distribution system in the interest of operating convenience and flexibility, maintenance, and service reliability; operating records show that most power outages occur on the low-voltage feeder circuits and not in the high-voltage distribution system.

The types of low-voltage distribution systems most applicable to paper mills and also to most industrial power systems are the radial and the secondary-selective arrangement. The radial system (Figure 2*A*), characterized by a single primary channel and substation, is suitable for general service where a power outage is not especially detrimental. The merits of the radial system are low cost and simplicity. This is the most common power distribution system. The secondary-selective system (Figures 2*B* and 2*C*) is especially suitable for continuous process loads, boiler house auxiliary supply, and whenever the service reliability and operating flexibility requires more than that offered by a straight radial system. Basically, this consists of two independent radial systems interconnected on the low-voltage bus through a normally open tie circuit breaker. This arrangement retains the operating simplicity of the radial system yet provides an excellent degree of service reliability economically.

The secondary-selective arrangement may be composed of two independent substations, with an external tie circuit between substations, or, where space is important, it may consist of a "double-ended" unit.

It should be noted that with the secondary-selective arrangement, *service reliability is the result of the system arrangement* in contrast to some methods where service reliability is dependent upon the reliability of the type of equipment.

Some advantages of the secondary-selective arrangement are:

1. Duplication of supply to the low-voltage bus, thus providing continuous service for the entire load area. The primary circuits

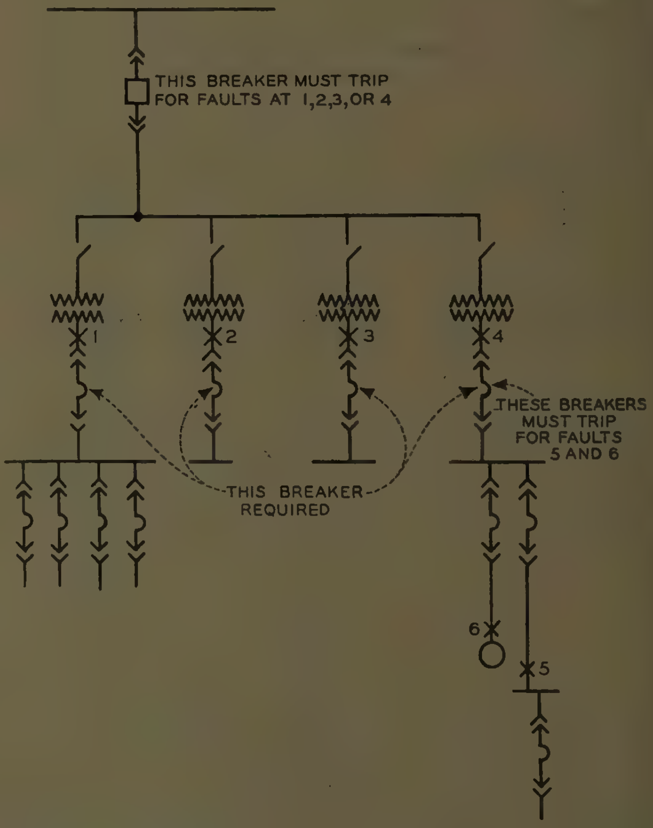

THIS BREAKER MUST TRIP FOR FAULTS AT 1,2,3,OR 4
1
2
3
4
THESE BREAKERS MUST TRIP FOR FAULTS 5 AND 6
THIS BREAKER REQUIRED
6
5

Figure 4. Arrangement for adequate protection for a low-voltage system

usually are separated physically throughout their entire length, making it improbable that a fault on one circuit will be transferred to the other circuit.

2. Retains the simplicity of the radial distribution system. No special relaying is required.

3. All transfer switching is performed by full-capacity air circuit breakers, thus contributing to safety. Transfer switching can be accomplished automatically, if necessary, at very little extra cost.

4. Under normal operation, both substations share in carrying the load, resulting in excellent voltage regulation and low system losses.

In the usual application the transformer secondary and tie circuit breakers are operated manually. However, where a higher degree of continuity of service is necessary, such as for essential boiler house auxiliaries and paper machines, the circuit breakers may be operated electrically to transfer power automatically in response to loss of voltage on either of the low-voltage buses.

An examination of low-voltage systems in existing mills showed that a modification of the secondary-selective arrangement was quite common; that was generally accomplished by normally-open tie circuits to all low-voltage substations in the same load area. Since most 460-volt and 575-volt loads in the medium and large mills are supplied by more than one substation, a judicious selection of substation rating and location can result in the use of the secondary-selective arrangement, and thus avoid the complicated switching associated with numerous tie circuits between all substations. The tie circuits in old mills often are switched by disconnecting switches; circuit breakers of proper rating should be used for such service as they offer the features of safety, can be opened or closed under load, and have the required interrupting ability for the system fault duty.

Looping low-voltage tie circuits are costly—ranging from $0.70 to $1.25 per ampere per 100 feet on an installed basis, depending upon the type of cable and method of installation; such looping arrangements usually are not necessary if the system is laid out properly.

The spot network arrangement (Figure 2*D*) is applicable where the highest degree of service reliability is necessary, such as for boiler house auxiliaries and especially in conjunction with the use of pulverized fuel, and for continuous process loads. However, very few paper mills or other industrials have adopted the network arrangement for distribution.

The primary-selective arrangement (Figure 3) is characterized by duplicate primary feeders but is otherwise a radial system. This arrangement has little to offer unless primary switching is done by power circuit breakers. Whenever a primary supply cable fails, it is necessary to de-energize the substation completely to disconnect that cable from the double-throw switch, as usually the cable terminations are in the same compartment as the switch. Maintenance on the switch requires de-energization of both primary feeders and thus loss of power to all other substations connected to those primary feeders. Therefore, when repairs and normal maintenance are considered, the primary-selective arrangement offers very little if any more service reliability than the simple radial system, especially if maintenance work must be done while the mill is in operation.

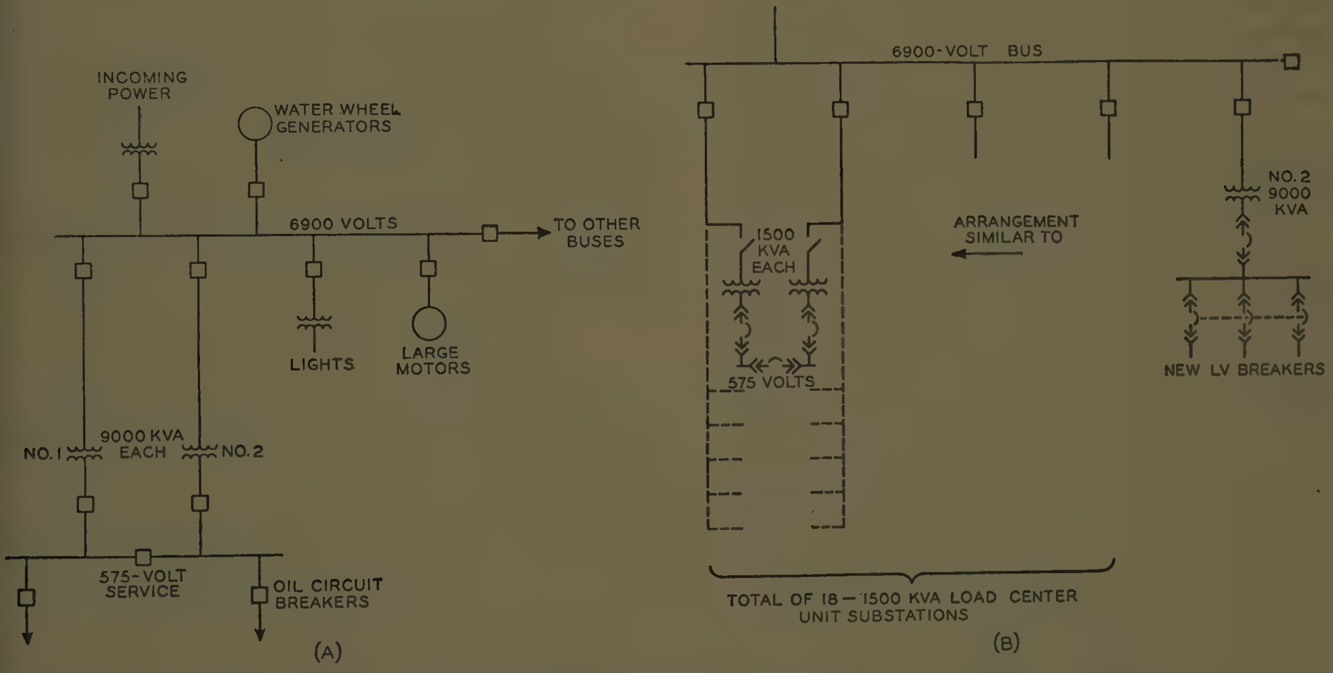


Figure 5. Diagrams showing changes in the 575-volt distribution system described in Case I

A—Existing mill *B—Plan for expansion and modernization*

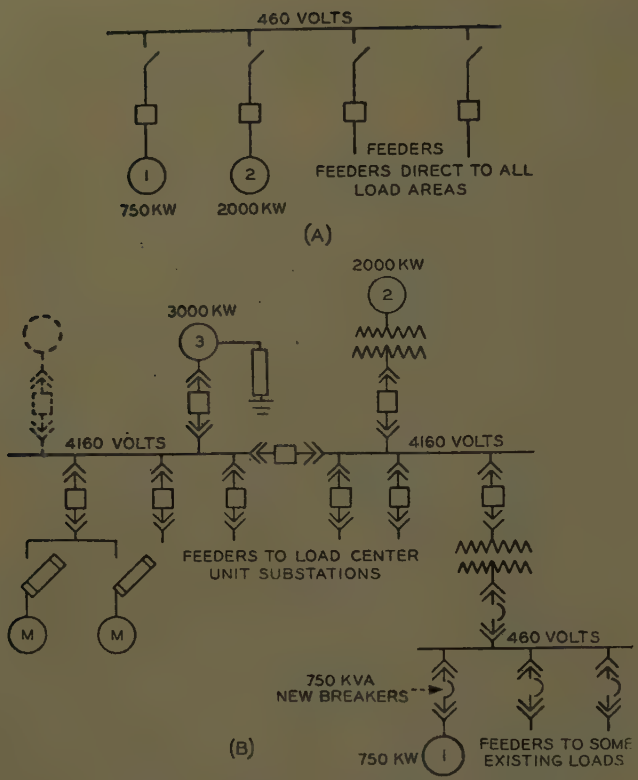


Figure 6. **Diagram showing changes in the distribution system of Case II**

A—Existing layout

B—Plan for expansion and modernization

There is also a hazard of closing the selector switch under short-circuit conditions in the event of a bushing or transformer failure. The natural tendency of an operator, when power is lost in his area, is to transfer the switch to the other position; thus, if the outage is due to a faulted transformer, he would switch the faulted transformer to a live circuit under short-circuit conditions with the resulting possibility of damage.

The primary-loop arrangement is a variation of the primary-selective arrangement. The proper method of sectionalizing the loop is by the use of the power circuit breakers.

It is suggested that the secondary-selective arrangement be used whenever the service reliability required is more than that afforded by a simple radial system. The secondary-selective arrangement permits any primary feeder, transformer, or main secondary circuit breaker to be taken out of service for maintenance without dropping service to the low-voltage bus.

The following are representative relative costs, on an installed basis, of these various types of distribution arrangements for 460-volt and 575-volt service as applied to medium and large-size mills.

1. Radial—100 per cent (base comparison).
2. Secondary selective—105 to 140 per cent, depending upon the reserve capacity in each transformer.
3. Spot network—115 to 150 per cent, depending upon the reserve capacity of transformers.
4. Primary selective—130 per cent.
5. Secondary selective with automatic throwover in response to loss of voltage—115 to 150 per cent.

It should be noted that the secondary-selective arrangement does not cost much more than a straight radial system, yet it provides duplicate power channels and a high degree of service reliability so essential to many paper mill processes.

OVERCURRENT PROTECTION

United States and Canadian codes have certain requirements regarding overload protection of transformers, depending upon the number of transformers connected to a primary feeder circuit. In general, this overload protection may be provided by an overload relay, either as a separate device or incorporated in the transformer secondary circuit breaker or transformer winding, or by a fuse on the transformer primary. In United States practice it is common to use a transformer secondary circuit breaker with a time delay overload attachment, or a primary fuse. Canadian practice is generally similar although another arrangement sometimes is used; in this arrangement the transformer secondary circuit breaker is omitted and transformer overload relay is used. Operation of the overload relay trips all feeder circuit breakers.

The most straightforward arrangement is the use of a transformer secondary circuit breaker with attached overload devices. This arrangement has several advantages: permits simplified interlocking necessary only between the transformer secondary circuit breaker and primary disconnecting switch; permits the use of feeder circuit breakers of smaller interrupting rating due to the principle of cascading, thus, generally, resulting in an over-all saving in the cost of circuit breakers. Permits future expansion of the radial system into the secondary-selective system; and affords back-up protection for the feeder circuit breakers. Figure 4 shows an arrangement with adequate protection for a typical low-voltage system.

EXPANSION AND MODERNIZATION

The use of some of the principles of power distribution is illustrated in the following examples which show how well adapted the load-center unit substation is for mill modernization and expansion.

Case I—Expansion of a Large Low-Voltage System. Figure 5*A* is a simplified 1-line diagram of part of the 575-volt system of a large Canadian mill. As shown, this mill now has a large 575-volt load supplied from two 9,000-kva transformer banks.

An additional 575-volt load of approximately 9,000 kva was required; the first thought was to add an additional transformer and duplicate of the existing units. How-

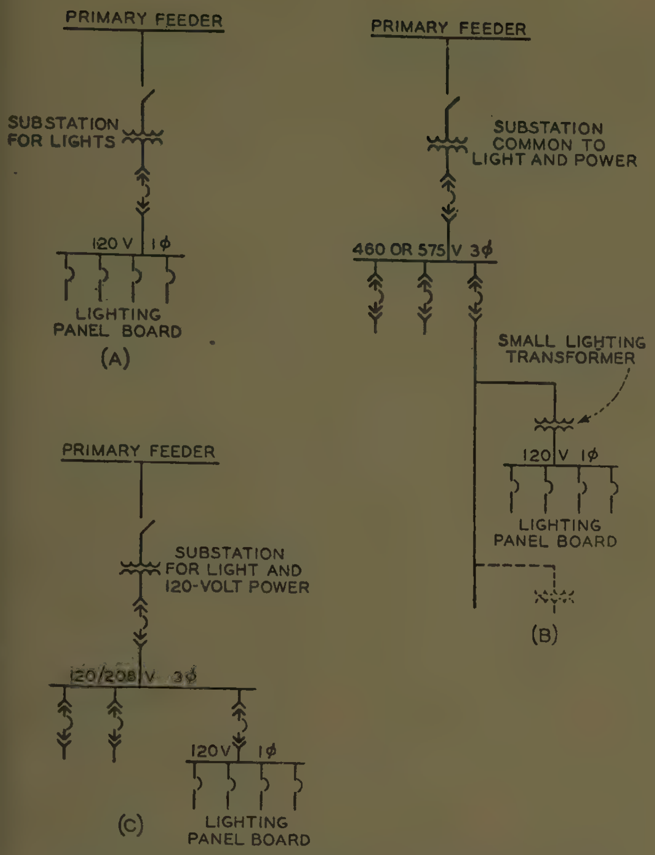


Figure 7. Methods for supplying mill lighting service

A—Separate substation for lighting
B—Substation for combined lighting and power load
C—Substation for 3-phase lighting

ever, an over-all study showed such an arrangement to be uneconomical. The arrangement adopted, and based on cost, is shown in Figure 5*B*. The following is a summary of this plan.

1. Purchase six 1,500-kva unit substations to supply the new 9,000-kva 575-volt load.
2. Replace the number 1 existing 9,000-kva transformer bank with 12 1,500-kva unit substations.
3. Transfer part of the load from the existing number 2 substation to the new 1,500-kva unit substations.
4. Replace the switchgear at number 2 substation with switchgear of adequate interrupting rating.
5. Use transformer number 1 as a spare for number 2.
6. Use the replaced switchgear whenever the fault duty is within the circuit breaker rating.

The main reason for the lower cost of the plan adopted was due to the saving in low-voltage switchgear; the fault duty on the 1,500-kva substations is moderate so relatively inexpensive circuit breakers can be used. This example shows the benefits available when consideration is given in over-all planning.

Case II—Modernization and Expansion of a Medium-Sized Mill. Figure 6*A* is a simplified 1-line diagram of a medium-sized American mill where all generation and utilization is at 460 volts. In this mill all circuit breakers are of inadequate rating and are to be replaced. In addition to this modernization program, there is an expansion program to consider for the immediate addition of a 3,000-kw turbine and the future addition of a 3,000- or 4,000-kw unit.

The power generation and distribution system selected is shown in Figure 6*B*. The main generation and distribution voltage is 4,160 volts, which is adequate for ample future load expansion. The existing 750-kw generator is retained on the 460-volt system to feed a local load, but will be taken out of service when the 3,000-kw unit is put in service. All other existing and new 460-volt loads will be served by unit substations from the main 4,160-volt bus. New motors above 200 horsepower in concentrated load areas will be operated directly from the main 4,160-volt system.

The existing 2,000-kw machine, which will be retained in the future, will be connected to the 4,160-volt system through a step-up transformer as it was impractical to rewind the generator for 4,160-volt service without loss of a substantial amount of generator capacity. (Derating of machines should be checked for each case when consideration is given to rewinding generators for higher voltages.)

SYSTEM GROUNDING

The advantages and disadvantages of a grounded low-voltage system are the same as those for a high-voltage system as explained in the companion article. Paper mills have not accepted yet the grounded low-voltage system, although there is a trend to grounded operation of high-voltage systems. It is significant to note, however, that the trend in other industrial plants in the United States is to the 460-volt grounded system, and particularly in large plants where significant savings can be made where 277/480-volt fluorescent lighting is used.

It is just as important to engineer a plant protective grounding system properly as it is the power distribution system proper. Only when sufficient attention is given to the over-all plant protective grounding requirements is there assurance of an adequate and safe grounding system. This applies equally well to ungrounded or grounded systems and to high- and low-voltage power systems.

The plant protective grounding system must have a direct path to ground in order to avoid unintentional transfer of ground currents among various metallic parts of the building and piping system, and to avoid differences of voltage between exposed metallic parts which might constitute a hazard to personnel. One example illustrating the result of improper plant protective grounding occurred in a plant with an extended underground piping system; there was an epidemic of pipe failures and leaks at crossover points each time a major fault occurred. After the piping network was properly bonded, these troubles disappeared. The main grounding system should be interconnected with the rest of the grounding paths via cable sheaths and plant piping, and the plant piping system should be bonded to the steel of the building structure. The low-voltage protective grounding system to motor and starter frames, busways, transformers, and switchgear should be interconnected with the main grounding system.

LIGHTING

The arrangement of separate substations for lighting (Figure 7*A*) costs more than the arrangement of substations for combined lighting and power load (Figure 7*B*), usually by 10 to 20 per cent in large mills, depending upon the extent of the lighting system. The trend in paper mills is towards the combined power and lighting arrangement, not only because of lower first cost but because of greater over-all service reliability, since the lighting is associated with only its mill area. When the secondary-selective power-distribution system, previously described, is used, reliability can be increased further by overlapping lighting areas.

In large office areas remote from the mill proper separate lighting transformers, for either single-phase (Figure 7*A*) or 3-phase (Figure 7*C*) service, can be used. The 120/208-volt service is advantageous since both single- and 3-phase power is available for both lighting and small motors. Incandescent lighting is used commonly in mill areas because of availability of special lamp enclosures for corrosive atmospheric conditions. Fluorescent lighting is common for office areas and is being used in some finishing and inspecting rooms.

Power requirements for illumination of approximately 35 foot-candles are 2 to 4 volt-amperes per square foot for fluorescent lights and 3 to 6 volt-amperes for incandescent lights. Power requirements for other illumination levels, such as 10 to 15 foot-candles common for mill areas, are approximately in proportion to the foot-candles of illumination.

METERING

This discussion is not intended to depreciate the desirability of metering equipment; some is desirable and even necessary, but extra metering equipment is expensive. For example, the inclusion of an ammeter and watt-hour meter for each feeder circuit increases substation price from 15 to 25 per cent. This price includes the necessary instrument transformers and extra compartment space necessary to mount the instruments and meters. Usually the only permanent metering necessary on a substation is an ammeter for indicating the total load and, perhaps, a watt-hour meter. Since paper mill loads are comparatively steady, periodic checks with suitable portable instruments usually will suffice for the feeder circuits.

Anchorage, Alaska, Power Plant

A unique source of electric power is Anchorage, Alaska's General Electric 5,400-kw marine turbine-electric power plant, the stern half of the former Government-owned tanker, "SS Sacketts Harbor." Firmly grounded to the city's shore, at high tide the ship stands in 25 feet of water but at low tide it is high and dry. Power lines, tied into anchorage's distribution system, lead from special rigging on the upper deck.

Power supplied to the city's lines fits readily as a result of the tubine-electric power plant's 3-phase 60-cycle 2,300-volt unity power factor rating. The turbine governor holds the frequency constant. The voltage of the main generator is regulated by an amplidyne generator and regulator which holds very constant terminal voltage on the main generator. One of the two 525-kw auxiliary turbine-generator sets supplied power for the ship's auxiliary electrical requirements and excitation.

Operation of the power plant is independent of the sea water except at high tide when the outside water aids in cooling the fresh water in the cargo tanks, heated by accumulation from the main condenser.

Incommensurables

A. B. FIELD
FELLOW AIEE

HAVING grown up with such quantities as π, ϵ, $\sqrt{2}$, we have become callous to their unreasonableness. Nevertheless, from time to time we are forced to ask ourselves what is wrong with our system of numeration that these quantities should refuse to be expressible either as fractions or as decimal quantities using a finite number of digits. Surely our system permits steps as fine as we please. What change of system would meet the needs, for instance, change from base 10? Or again, we ask, how many of these rebels are there? Is there a mere sprinkling? Is there a generic incommensurable unit—call it I—whereby all incommensurable quantities can be expressed as so many ordinary units plus so many I units, $p+qI$, a method we are used to for complex quantities?

It takes but little examination to find unexpected answers to a number of such questions, and to reveal the fact that between any two numerical limits we choose to set, no matter how close together, we readily can place a million incommensurables, that is, quantities not one of which is expressible numerically.

But first let us clear the field a little, because we have a sufficient infinity of these quantities left even after a major weeding operation. For instance, while π is known to be incommensurable, and therefore also p plus π and q multiplied by π, let us not consider the members of these two groups to have *independent* incommensurable natures, but treat them all as basically a single incommensurable. However, since the two groups constitute an infinity of distinct quantities, we hardly can call all of them one incommensurable, and we must use a modified terminology. Perhaps we may be allowed to talk for the present of incommensurable "tails" and distinguish between those which are independent and those which are interrelated, the "tail" signifying all that is left of an incommensurable quantity after taking away the grosser part. It is a matter of indifference where we make the separation between body and tail. Suppose we say we will do so after the tenth decimal digit in which instance all the tails to be considered here are less than 10^{-10}. Our proposed weeding, then, determines that if one such tail can be reached from another one by multiplying it by any numerical factor whatever and/or adding any numerical quantity (a decimal quantity of course), these two tails are not independent. Granted this understanding, let it be said at once that there is not the slightest difficulty in writing down a precise representation of a group of any number of tails lying between say 1×10^{-11} and 2×10^{-11}.* This may not be particularly startling, but surely it is astonishing that millions of these can be all independent, that if T and T' are any two out of this near-infinity we cannot express T' in the form $p+qT$ with any values of p and q which can be expressed numerically. Either p or q would have to be incommensurable as well as T and T'.

Mathematicians tell us that they have devised a system involving a "noncountable continuous aggregate" wherein incommensurables become rationalized,[1] but no ordinary modification of our system of numeration, leaving it a step by step one, can have any such effect. Some remarkable facts concerning incommensurables follow at once from simple algebra, for instance:

1. If X and n are integral, then $X^{\frac{1}{n}}$ must be incommensurable if it is not integral.
2. If $X^{\frac{1}{2}}$ is a surd it never can be expressed in terms of any other dissimilar surd of the same degree by a linear relation, that is, these incommensurables are all independent. This is true whether X be integral or not, and we are told there is an infinity of second degree dissimilar surds even with X integral.
3. An incommensurable raised to a fractional power may be commensurable, but not if the numerator of the fractional index is unity.
4. The product of two independent incommensurables may be commensurable, but not the sum.
5. An incommensurable may occur as the sum of an infinite series, or as an infinite product, or as a nonterminating continuous fraction. For instance, expressions for π in all these forms are well known.

These few statements are not given as exclusive. Even as they stand they can be generalized considerably, but they are simple and the reader may find pleasure in pursuing them further.

REFERENCE

1. Encyclopedia Britannica, 11th edition, volume 19, page 850.

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* As typical of such a group we have the recurring simple continuous fraction

$$I=2\times10^{-11}\left[\frac{1}{1+}\;\frac{1}{a+}\;\frac{1}{b+}\;\frac{1}{c+}\;\frac{1}{1+}\cdots\right]$$

and by giving each of a, b, c every value from 1 to 1,000, and ringing the permutations, we have $(1{,}000)^3$ or 10^9 values of I, every one of which is incommensurable. Every value of I lies between that of the first convergent, that is, 2×10^{-11} and that of the second convergent, the lowest value of which is 1×10^{-11}. If we desire to set out these values of I in descending order of magnitude we do so by starting with $a=1{,}000$, $b=1$, $c=1{,}000$, and successively reducing c until it becomes unity (1,000 values). We then make b equal to 2 and start with c again at 1,000 repeating the first process. We carry this on until b has reached 1,000 when we start the third stage with $a=999$, $b=1$, $c=1{,}000$. These 10^9 incommensurable tails are not all independent as there are some peculiar and very interesting relations between some of them, for example, the following are related linearly in pairs: Each pair obtained by interchanging the values of a and b when $c=1$; or interchanging b and c when $a=1$; or interchanging c and a when b has any value; or again, the pair $a=1$, $b=1$, $c=1$; $a=5$, $b=1$, $c=5$, but this pair is quite independent of say $a=3$, $b=1$, $c=3$.

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New AIEE Committee Organization

THE ADMINISTRATION of committee activities of the Institute gradually is evolving toward greater unification of groups which have related interests. The board of directors, at its April meeting in Worcester, Mass. (*EE, June '47, pp 597–8*), set in motion a series of changes intended to revitalize the entire committee structure. Immediately after the meeting, Blake D. Hull, then the presidential nominee, started the formation of the new committee organization in order to enter upon the new year with a full personnel.

Prior to the Worcester meeting, the technical committees had been operating informally in a group or divisional organization as suggested by the directors at their Asheville, N. C., meeting in 1946 (*EE, June '46, pp 269–70*). At Worcester, the Asheville resolution was amended to read as follows:

> Resolved that it is the sense of the board of directors that the development of the technical committee activities of the Institute should be guided by the following principles:
>
> 1. That such additional technical committees should be organized as may be needed to cover the important items of electrical technology.
>
> 2. That these technical committees should be grouped in appropriate divisions or groups with a co-ordinating committee for each group fairly compact in numbers and consisting essentially of a group chairman and the chairmen of the technical committees comprising the group.
>
> 3. That each year the group co-ordinating committees make informal recommendations to the presidential nominee through the secretary on the membership and organization of the whole technical committee structure, including at least two alternates for every co-ordinating committee chairmanship.
>
> 4. That in such recommendations a reasonable turnover of the committee personnel be the intention. Further, that it is the intent of this board that the responsible committees should proceed with such changes as they may determine to be necessary and proper to effectuate these principles unless the proposed changes are at variance with either the constitution or the bylaws, in which event they shall be referred back to the board for further consideration.

The directors voted to establish initially four co-ordinating committees for the technical committees, and also to establish several new technical committees in addition to those previously established at their January and October meetings. The new technical committee setup (including several changes adopted by the board of directors on August 11, 1947) follows:

Power Co-ordinating Committee

Carrier current committee
Electronic power converter committee
Insulated conductor committee
Power generation committee
Protective devices committee
Relay committee
Rotating machinery committee
Substation committee
Switchgear committee
System engineering committee
Transformer committee
Transmission and distribution committee

Industry Co-ordinating Committee

Chemical, electrochemical, and electrothermal committee
Electric heating committee
Electric welding committee
General industry applications committee
Industrial control committee
Industrial power systems committee
Mining and metal industry committee

Communication and Science Co-ordinating Committee

Basic sciences committee
Communication committee
Electronics committee
Instruments and measurements committee
Nucleonics committee
Therapeutics committee

General Applications Co-ordinating Committee

Air transportation committee
Domestic and commercial applications committee
Land transportation committee
Marine transportation committee
Production and application of light committee

In general the name of the committee describes its functions. Other duties are defined in sections 65, 85, 86, and 108 of the bylaws of the Institute.

No changes in the constitution and no major changes in the bylaws were required to accomplish the reorganization. As before, all committees are directly responsible to the board of directors; as before, and as provided in the bylaws "in respect of matters affecting standardization or nomenclature, the several committees named shall submit to the Standards committee such recommendations as they may deem proper;" as before, "in respect of papers and discussions, these committees shall report to the technical program committee to correlate the work of their committees in such a manner as effectively will provide adequate opportunity for discussion of each of the various topics included within the scope of Institute activity, and to arrange the presentation and discussion of such papers as may receive its approval." The chairman of each technical committee will continue to be a member of the technical program committee which also includes the chairmen of technical co-ordinating committees, the committees on planning and co-ordination, safety, Standards, education, and research. The technical committees themselves will do the work of co-ordinating and correlating their activities within their own groups.

One year of experience with this organization scheme leads to the belief that a combination of flexibility and efficiency can be achieved which will give complete and current coverage to all areas of the large field of technical activity of the Institute. Subjects, papers, and duties can be transferred among committees and among groups or divisions. Co-operation, under the co-ordinating committees, comes about by common consultation and common consent.

A similar grouping of activities will be tried among the general committees. At Worcester the directors, in addition to endorsing the principle of divisional organization, voted to establish two new co-ordinating committees, one on professional and one on administrative activities, for the coming year. Also established by the directors at their Worcester meeting, is a new general committee, the management committee, which is included in the professional activities group. The new groups follow:

Administration Group Co-ordinating Committee

Board of examiners
Constitution and bylaws committee
Headquarters committee
Institute publicity committee
Members-for-life fund committee
Membership committee
Transfers committee

Professional Activities Co-ordinating Committee

Award of Institute prizes committee
Charles LeGeyt Fortescue fellowship committee
Code of principles of professional conduct committee
Edison Medal committee
Education committee
Lamme Medal committee
Management committee
Registration of engineers committee
Student Branches committee

Not included in any divisional group are the remaining general committees which will continue to operate as at present. These are

Finance committee
Planning and co-ordination committee
Publication committee
Research committee
Safety committee
Sections committee
Standards committee
Technical program committee

The committee on planning and co-ordination, however, will include within its membership the chairmen of the six co-ordinating committees. The divisional structure of the general committees will be worked out in more complete detail as the next administrative year progresses.

The following sections list the various technical committees. The co-ordinating committee is given first, then the name and scope of the various committees represented in that particular co-ordinating committee.

Personnel are listed on pages 1031-8 of this issue.

Power Co-ordinating Committee

M. J. Steinberg, *chairman*, Consolidated Edision Company of New York, Inc., 4 Irving Place, New York, N. Y.
H. W. Collins, *vice-chairman*
R. T. Henry
Frank Thornton, Jr.
Ex-officio: chairmen of technical committees in the power group

CARRIER CURRENT COMMITTEE

Scope—Treatment of all matters in which the dominant factors are the design, construction, and operation of equipment and circuits for the application of carrier currents in the generation, transmission, and distribution of electric power. Included in the scope of this committee shall be treatment of the following:

Carrier current equipment and circuits for
  Relaying
  Control (supervisory, load, frequency, and so forth)
  Metering
  Communication as applied to power system use
also:
Line traps
Coupling capacitors

ELECTRONIC POWER CONVERTER COMMITTEE

Scope—Treatment of all matters in which the dominant factors are the design, construction, and operation of equipment and circuits for the electronic conversion of electric energy into other phases of electric energy in the generation, transmission, distribution, and utilization of electric power. This scope shall not include hot-cathode-type converters which have been assigned to the hot cathode electronic power converters subcommittee of the electronics committee. There shall be included in this scope treatment of the following:

Electronic converters for motor control (joint with industrial control committee)
Electronic power rectifiers and inverters
Electronic frequency changers

Matters relating to electronic converters specifically designed for applications covered by certain other technical committees such as communication, transportation, industrial power systems, and electrochemical applications may be treated jointly with that committee if emphasis is on general principles; or exclusively by the application committee if emphasis is on the particular requirements of the application.

INSULATED CONDUCTOR COMMITTEE

Scope—Treatment of all matters in which the dominant factors are the design, construction, and operation of insulated conductors and the accessories thereto used in the generation, transmission, distribution, and utilization of electric power. Included in this scope shall be treatment of the following:

Cable supply systems (including solid, oil-filled, and gas-filled cables)
Insulated wire and cable
Accessories (including potheads, wiring ducts, and conduit, not including insulated bus runs as in metal-clad switchgear)
Structures (joint with transmission and distribution committee)
Cable characteristics
Insulations
Sheaths and coverings
Utilization wiring systems

Special purpose cables
Tests and measurements

Matters relating to insulated conductors specifically designed for applications covered by certain other technical committees such as communication, transportation, and electric heating may be treated jointly with that committee if emphasis is on general principles; or exclusively by the application committee if emphasis is on the particular requirements of the application.

POWER GENERATION COMMITTEE

Scope—Treatment of all matters relating to the design, construction, and operation of electric power generating stations, including auxiliary equipment incidental thereto (where such equipment is not otherwise specifically assigned to other technical committees).

Treatment of all matters pertaining to the design, construction, and operation of steam boiler plants, dams, reservoirs, nuclear piles, and other primary sources of energy to prime movers; also the prime movers themselves used in the generation of electric energy.

Treatment of all matters relating to the economics of generation and supply of electric power within individual generating stations.

Included in this scope shall be treatment of the following:

Prime movers (hydro, steam, oil, gas, nuclear, wind power)
Speed governors for prime movers
Station load and frequency control (joint with system engineering committee)
Control systems (joint with substation committee)
Excitation systems and voltage regulators
Station design (generating plant)
Auxiliaries and accessories
Production costs—design and operating economics (separate station)
Co-ordination of prime mover and electric machine design
Bus design (joint with switchgear and substation committees)

PROTECTIVE DEVICES COMMITTEE

Scope—Treatment of all matters in which the dominant factors are the design, construction, and operation of devices and equipment to limit or prevent damage to electric power generation, transmission, or distribution systems, or equipment; such damage arising from excessive current, voltage, or from lightning. Included in this scope shall be treatment of the following:

Capacitors (where used as protective devices)
Lightning protective devices (such as arrestors, protector tubes, air gaps, and expulsion gaps)
Fault limiting devices (including neutral grounding devices)
Lightning investigations (joint with transmission and distribution committee)
Reactors and grounding transformers (joint with transformer committee)

Matters relating to protective devices specifically designed for applications covered by certain other technical committees such as industrial control, industrial distribution systems, or communication, may be treated jointly with that committee if emphasis is on general principles; or exclusively by the application committee if emphasis is on the particular requirements of the application.

RELAY COMMITTEE

Scope—Treatment of all matters in which the dominant factors are the design, construction, and operation of protective relays including all matters necessary to the functioning of such relays employed in the generation, transmission, and distribution of electric energy. Included in this scope shall be treatment of the following:

Relays and automatic devices (fault and load discriminating)
Relay protective schemes, including relay co-ordination
Potential devices
Bushing and instrument transformers (joint with instruments and measurements committee)

Matters relating to relays specifically designed for applications covered by certain other technical committees such as industrial control, communication, and transportation may be treated jointly with that committee if emphasis is on general principles; or exclusively by the application committee if emphasis is on the particular requirements of the application.

ROTATING MACHINERY COMMITTEE

Scope—Treatment of all matters in which the dominant factors are the requirements. design, construction, and operation of rotating machinery for the generation of electric energy or its conversion into other forms of energy. There shall be included in this scope treatment of the following:

Synchronous machines
Induction machines
D-c machines
Single phase and fractional horsepower machines
Motor generator sets
Rotating frequency changers
Rotating phase balancers
Synchronous converters
Insulation and dielectric problems related to rotating machinery

Matters relating to rotating machinery specifically designed for applications covered by certain other technical committees such as electric welding, transportation, or communication may be treated jointly with that application committee if the emphasis is on general principles; or exclusively by the application committee if the emphasis is on the particular requirements of the application.

SUBSTATION COMMITTEE

Scope—Treatment of all matters in which the dominant factors are the electrical and structural design, construction, installation, operation, and control of automatic, semiautomatic, and nonautomatic substations, including switching and transformer stations.

Included in the scope of this committee shall be treatment of the following:

Automatic, semiautomatic, and nonautomatic substations
Switching stations
Fundamental single line wiring diagrams
Bus design (joint with switchgear and power generation committees)
Automatic and supervisory control systems (joint with power generation committee)
Supervisory control devices
Structural arrangements for substations
Telemetering (joint with instruments and measurements committee)
Insulation co-ordination (joint with transmission and distribution committee)

SWITCHGEAR COMMITTEE

Scope—Treatment of all matters in which the dominant factors are the design, construction, and operation of devices or assembled gear to establish (make), interrupt, or change connections in an electric circuit under normal or abnormal conditions. Included in this scope shall be treatment of the following:

Power circuit breakers
Large air circuit breakers
Low-voltage air circuit breakers
Switchgear assemblies
Switches
Insulating fluids (joint with transformer committee)
Bus design (joint with power generation and substation committees)
Insulation, insulators, and hardware for switchgear
Automatic reclosers
High-voltage fuses and cutouts (above 600 volts)

Matters relating to switchgear or switchgear devices specifically designed for applications covered by certain other technical committees such as industrial control, communication, electronics, and transportation may be treated jointly with that committee if emphasis is on general principles; or exclusively by the application committee if emphasis is on the particular requirements of the application.

SYSTEM ENGINEERING COMMITTEE

Scope—Treatment of all matters in which the dominant factors are the requirements, planning, co-ordination, operation, and economics of interconnected electric generating, transmission, and distribution systems. Included in this scope shall be treatment of the following:

Interconnected system planning
Frequency and load control (joint with power generation committee)
Load dispatching
Economics of system and unit operation
Engineering of system expansion
Interconnection contracts

TRANSFORMER COMMITTEE

Scope—Treatment of all matters in which the dominant factors are the design, construction, and operation of transformers, reactors, and other similar equipment. Included within this scope shall be treatment of the following:

Transmission and distribution transformers
Voltage and load regulators (step and induction regulators)
Reactors and grounding transformers (joint with protective devices committee)
Specialty transformers and regulating transformers
Railway service transformers
Test transformers
Constant current transformers
Insulating fluids (joint with switchgear committee)
Insulation and dielectric problems relating to transformers
Insulators and hardware for transformers

Matters relating to transformers and regulators specifically designed for applications covered by certain other technical committees such as relays, electronics, protective devices, communication, may be treated jointly with that committee if emphasis is on general principles; or exclusively by the application committee if emphasis is on the particular requirements of the application.

TRANSMISSION AND DISTRIBUTION COMMITTEE

Scope—Treatment of all matters in which the dominant factors are considerations of economical and technical design, theoretical and experimental performance, installation, and service operation of that part of electric power systems which serve to transmit electric energy between the generating source or substation and the service.

Treatment of all matters involving substations themselves including switching and transforming stations are not within the scope of this committee, except in the broad aspects of the application of a substation as a whole.

Treatment of matters involving industrial distribution systems shall not be included within this scope unless such systems are interconnected with an electric power utility, in which case the action shall be joint with the committee on industrial power systems.

Included in this scope shall be treatment of the following:

Overhead and underground transmission and distribution systems
Overhead conductors
Fault current studies
System stability
Lightning investigations (joint with protective device committee)
Structural co-ordination
Insulation co-ordination (joint with substation committee)
Inductive co-ordination
Corona
Towers, pole, insulators, and hardware
Capacitors (except those used for protective devices)

Industry Co-ordinating Committee

Herbert Speight, *chairman*, Westinghouse Electric Corporation, 40 Wall Street, New York, N. Y.
J. J. Orr, *vice-chairman*
J. Elmer Housley
Ex-officio: chairmen of technical committees in the industry group

CHEMICAL, ELECTROCHEMICAL, AND ELECTROTHERMAL COMMITTEE

Scope—Treatment of all matters in which the dominant factors are the generation of electricity through chemical processes, and the application of electricity to chemical or metallurgical operations (exclusive of electric welding and the phenomena of the arc insofar as it is concerned with the deposition of metal in welding, which is a function of the electric welding committee, and exclusive of magnetics, which is a function of the basic sciences committee), including the relations, installation, and operation of the devices necessary thereto, and the requirements of specialized devices, materials, or construction peculiar thereto.

ELECTRIC HEATING COMMITTEE

Scope—Treatment of all matters in which the dominant factors are the requirements, selection, installation, and operation of machines, devices, and equipment relating to electric heating of all kinds, including dielectric and induction, radiation, resistance, and high temperature furnaces. Design and theory of devices shall be handled by consultation with electronics or other committees as required.

ELECTRIC WELDING COMMITTEE

Scope—Treatment of all matters in which the dominant factors are the requirements, design, construction, selection, installation, and operation of machinery and devices relating to electric welding, including studies of the electromagnetic phenomena of the arc insofar as it is concerned with the deposition of metal in welding. Such subjects as electric welding methods and the electric machinery and control equipment specially designed for welding are properly within the scope of this committee.

GENERAL INDUSTRY APPLICATIONS COMMITTEE

Scope—Treatment of all matters in which the dominant factors are the requirements, selection, installation, and operation of machinery and devices relating to machine tools and to the processing and/or fabrication (assembly) of nonmetallic materials. Such materials include textiles, rubber, paper, plastics

The problems relating to assembly line processes of all materials are considered within the scope of this committee.

INDUSTRIAL CONTROL COMMITTEE

Scope—Treatment of all matters in which the dominant factors are the design, construction, and performance of industrial control, and the way in which it serves to govern in some predetermined manner the electric power delivered to the apparatus to which it is connected.

INDUSTRIAL POWER SYSTEMS COMMITTEE

Scope—Treatment of all matters in which the dominant factors are the requirements, selection, co-ordination, installation, and operation of machines, devices, and equipment necessary for generating and transmitting electric power within an industrial plant for use solely by that plant. (Actual design of devices and equipment not included.) Design of distribution systems within the industrial plant are a part of the scope of this committee.

When such industrial systems are interconnected with public systems, the action shall be joint with the committee on power generation or on transmission and distribution.

MINING AND METAL INDUSTRY COMMITTEE

Scope—Treatment of all matters in which the dominant factors are the requirements, selection, installation, and operation of machinery and devices relating to the processing of metal and those relating to mining of any kind.

Matters pertaining to blast furnaces, metal rolling, and metal drawing are properly within the scope of this committee.

Communication and Science Co-ordinating Committee

W. R. G. Baker, *chairman,* General Electric Company, Electronics Department, Thompson Road, Syracuse, N. Y.
Truman S. Gray, *vice-chairman*
O. E. Buckley
F. A. Cowan
Ex-officio: chairmen of technical committees in the communication and science group

BASIC SCIENCES COMMITTEE

Scope—Treatment of all matters in which the dominant factor is electrophysics, and which are of such novel character as to be unapplied in any apparatus or field of application within the scopes of the other technical committees, or which are of such generality as to be significant within the scopes of several technical committees. Such subjects as general circuit theory, electrostatics, mathematical treatises, magnetics, general electrical units, and nomenclature are properly within the scope of this committee.

COMMUNICATION COMMITTEE

Scope—Treatment of all matters in which the dominant factor is the electrical transmission of intelligence (exclusive of supervisory control, which is a function of the substations committee, and railway signaling, which is a function of the land transportation committee), including methods, materials, devices, and construction to accomplish the result. Such subjects as telegraphy; telephony; program transmission; telephotography; television; police alarm, fire alarm, burglar alarm and traffic control systems; messenger calls; and time service are within the scope of this committee. Where communication lines are utilized in other fields, for example, the communication requirements of electric power systems and railways, or where problems of inductive coordination arise, treatment shall be joint with the respective technical committees concerned.

ELECTRONICS COMMITTEE

Scope—Treatment of all matters in which the dominant factor is electronics, particularly those dealing with the design, characteristics, or behavior of devices of an electronic nature, or of the circuits associated with them. The treatment of complete equipments or systems may be considered within the scope of this committee if they depend predominantly on electronic devices for their operation. If the field of application of such equipments or systems falls also within the scope of other technical committees, action with those committees may be joint.

INSTRUMENTS AND MEASUREMENTS COMMITTEE

Scope—Treatment of all matters in which the dominant factor is the measurement of electrical quantities, both absolute and relative, and the measurement of other quantities by electrical methods, including the devices necessary thereto. Where novel instruments and novel methods of electrical measurement are in papers, even though measurement is not the prime objective, then action shall be joint with the respective technical committee concerned.

Telemetering is assigned primarily to the committee on instruments and measurements and handled by a joint subcommittee comprised of members of both the committees on substations and instruments and measurements. Telemetering problems in connection with automatic stations will be assigned by the chairman of the committee on instruments and measurements to members of the subcommittee who are also members of the committee on substations. Telemetering problems of a more general nature will be assigned by him to members of both main committees, and where the problem is simply measurements it will be assigned only to members of the committee on instruments and measurements (as per joint agreement between the committees on automatic stations and instruments and measurements, January 29, 1935).

NUCLEONICS COMMITTEE

Scope—Treatment of all matters in which the dominant factor is nucleonics, particularly that dealing with the design, characteristics, or behavior of devices of a nucleonic nature, or of the systems associated with them. The treatment of complete equipments or systems may be considered within the scope of this committee if they depend predominantly on nucleonic principle for their operation. If the field of application of such equipments or systems falls also within the scopes of other technical committees, action with those committees shall be joint.

THERAPEUTICS COMMITTEE

Scope—Treatment of all matters in which the dominant factors are the application of electric power to sanitation equipment, such as air-cleaning and sterilizing devices, and to the promotion of health and the analysis and treatment of disease or defects of the human body, such as X-ray equipment, diathermic equipment, cardiographs, investigations not directly applying to the human body but relating to health, and electric devices suitable for such purposes; the study of harmful effects of electric currents and radiations of electric devices upon the human body and means for the prevention of such effects, and so forth, are properly within the scope of this committee.

Where certain devices are suitable for both therapeutic and industrial purposes, such as some X-ray equipment, or for therapeutic and other scientific investigations, or for sanitation and air-conditioning of domestic and commercial premises, action shall be joint with the industrial power applications committee, the basic sciences committee, or the domestic and commercial applications committee, respectively; also, when appropriate, with the safety committee.

General Applications Co-ordinating Committee

S. G. Hibben, *chairman,* Westinghouse Lamp Division, Bloomfield, N. J.
C. C. Whipple, *vice-chairman*
Elgin B. Robertson
Ex-officio: chairmen of technical committees in the general applications group

AIR TRANSPORTATION COMMITTEE

Scope—Treatment of all matters in which the dominant factors are the design, installation, and performance of airplane equipment, including batteries, generating equipment, voltage regulators, instruments, wiring devices, motors, special controls, reverse current cutouts, bonding, shielding, filtering, inverters, dynamotors, lightning detection and protection, lighting (interior and exterior), system characteristics, weight-power relationships, and heating devices. With respect to communication and navigation; ground lighting; electric testing equipment for measuring strain, vibration, noise, corrosion, and so forth; and electric welding of airplane structures; action should be in co-operation with the respective AIEE technical committees in these fields and similar committees of other organizations.

DOMESTIC AND COMMERCIAL APPLICATIONS COMMITTEE

Scope—Treatment of all matters in which the dominant technical factors are the interior supply and utilization of electric power in domestic premises, such as single or multiple dwellings, garages, and other accessory structures, and in institutional buildings such as hospitals, schools, libraries, and so forth. Such subjects as control, interior wiring, heat-operated and motor-operated appliances or equipment for use in domestic, commercial, or institutional premises, including elevators and escalators, are properly within this scope. Subjects relating to the production and application of light, as such, are within the scope of the production and application of light committee.

LAND TRANSPORTATION COMMITTEE

Scope—Treatment of all matters in which the dominant factors are the requirements, design, selection, relation, and operation of electric apparatus and material for transportation (exclusive of air and marine transportation, which are functions of the air transportation and marine transportation committees) of passengers and freight and the economic questions incident thereto. Such subjects as the electrification of steam railways, street railways, pantograph trolleys and overhead catenaries, electric locomotives (oil-electric, gasoline-electric, or 3-power locomotives), multiple-unit cars, electric-traction motors, main and auxiliary control equipment, railway substations, mercury-arc rectifier applications, and railways signaling and automatic train control are within the scope of this committee.

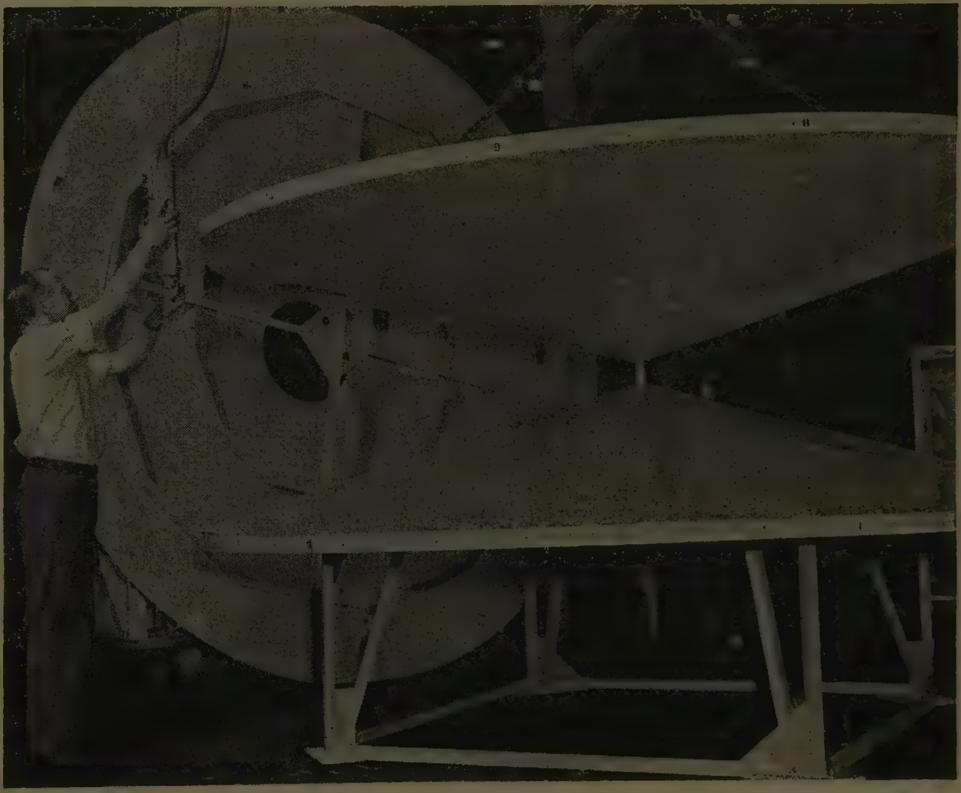
MARINE TRANSPORTATION COMMITTEE

Scope—Treatment of all matters in which the dominant factors are the application, relation, and installation of electric machinery and materials of whatever nature on shipboard, and the requirements for specialized devices, materials, or constructions peculiar to such application.

PRODUCTION AND APPLICATION OF LIGHT COMMITTEE

Scope—Treatment of those matters in which the dominant factor is the application of electric energy through its conversion into light, including necessary materials, devices, and mechanisms, insofar as these matters are considered of interest and value to the members of the Institute. This committee functions as a liaison between the Institute and various organizations dealing with the production and utilization of light, such as the Illuminating Engineering Society, the Optical Society of America, and others. Its activities include translating the theoretical and technical accomplishments of those organizations into terms of the practical aspects of the production and application of light, thereby serving to inform Institute members of important progress in this field. Where problems of electrical supply service, voltage, or distribution are involved, action shall be joint with the transmission and distribution committee.

Biconical Television Antenna



A newly-developed General Electric Company television receiving antenna, known as a "chicken brooder" antenna, will pick up local programs from mobile units without being aimed at the units. Sixteen times more sensitive than a vertical half-wave antenna usually used for this application, it will be employed by television station WMAL in Washington, D. C. The antenna is constructed with three aluminum sections, each of which is conical in shape, ten feet in diameter, and weighs about 100 pounds. A dipole between the first two sections, which are assembled with the apexes of the cones facing each other, forms the actual receiving antenna to which signals are directed by the cone-shaped structure

INSTITUTE ACTIVITIES

Midwest General Meeting to Be Held in Chicago, Ill.

Arrangements are in progress for the program of the Midwest general meeting to be held in Chicago, Ill., November 3–7, 1947. Headquarters for the meeting will be in the Congress Hotel. A full program of broad general interest, which is appropriate for the locality of the meeting, will be presented in combination with inspection trips, entertainment, and special activities for the visiting women. The National Electronics Conference at the Edgewater Beach Hotel, November 3–5, and the second International Lighting Exposition at the Stevens Hotel, November 3–7, which is concurrent with the AIEE meeting, assure a busy week in Chicago. A joint session with the National Electronics Conference will be held at the Edgewater Beach Hotel, and all other sessions which have to do with electronic applications and communication will be scheduled on the last two days of the meeting to avoid conflict with the National Electronics Conference sessions.

GENERAL SESSIONS

The opening session of the meeting will be addressed by Blake D. Hull, AIEE president, on the subject, "Ceiling Unlimited." In another general session, Doctor Enrico Fermi, department of physics, University of Chicago, will speak on certain aspects of nucleonics. Still another general session will feature an address by E. O. Shreve on "Business Looks to the Future." Mr. Shreve is president of the United States Chamber of Commerce and a vice-president of the General Electric Company, on leave.

TECHNICAL SESSIONS

In the field of transmission and distribution a symposium will be held on the Tidd 500-kv test lines. A series of papers will be presented, outlining the factors involved in high-voltage transmission and describing the field test setup for determining corona on transmission lines up to 500 kv. Papers by well-known authors will include descriptions of the station, towers, conductors, transformers, arresters, and instrumentation.

Also in the field of transmission and distribution another session is in prospect, which will include papers on switching high-voltage transmission lines and the transient voltage rise in transformers resulting from interruption of exciting current, as well as gaseous insulation for high-voltage apparatus.

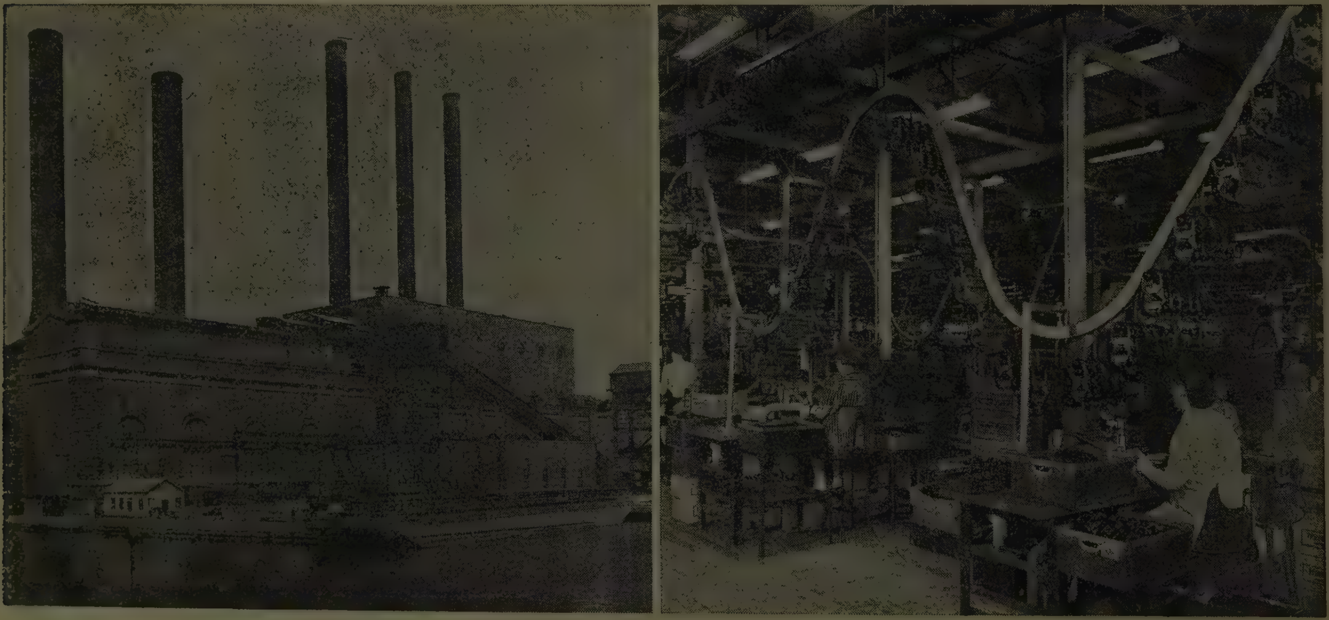
In the field of power generation, several papers will deal with the application of probability methods to determine generating reserve capacity. Other power generation papers will include such subjects as generator stability at low excitation, resynchronizing of generators, and suddenly applied loads on a variable-ratio frequency changer.

Among the several technical conferences which are in prospect is an exploratory conference on electronic relay applications. Wide differences of opinion prevail in regard to the extent to which electronic devices can be and should be applied in protective relaying schemes. The exchange of information between people keenly interested in electronics and those familiar with protective relaying schemes will be of considerable value.

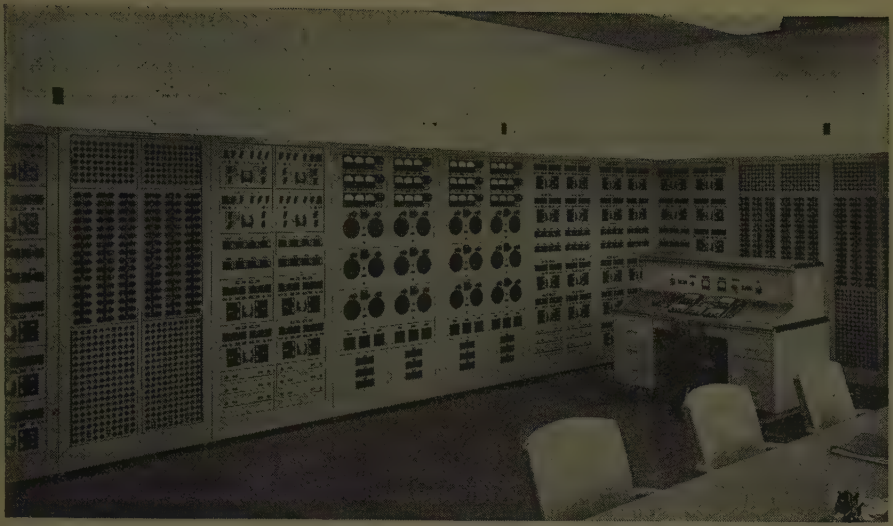
Some of the papers in a session on communication will treat the subjects of frequency division techniques for a coaxial cable network and a general mobile telephone system.

Technical conferences covering the industrial field also will be held. These will have to do with power distribution, control, and battery charging and maintenance in steel mills, as well as in railroad terminals.

Another session is in prospect, at which a preliminary report on "Interior Wiring Design for Public and Commercial Buildings" by the subcommittee on interior wiring design for commercial buildings will be presented for discussion.



Inspection trips planned for the AIEE Midwest general meeting include the historic Fisk Station of the Commonwealth Edison Company (left) which is the oldest, dating from 1903, and the second largest, 311,000 kw, in Chicago; and the Archer Avenue plant of the Western Electric Company's Hawthorne Works where, at right, the finishing operation on telephone handset handles is shown



The a-c network calculator board at Armour Research Foundation of the Illinois Institute of Technology, scheduled for inspection during the AIEE Midwest general meeting

INSPECTION TRIPS

A number of interesting inspection trips in and around Chicago have been planned as part of the meeting program. They include the Fisk Station of the Commonwealth Edison Company and the Hawthorne Works of the Western Electric Company on Tuesday afternoon; the Carnegie Illinois Steel Company and the Museum of Science and Industry on Wednesday afternoon; the Marshall Field store on Wednesday evening; Armour Research Foundation and the electromotive division of General Motors Corporation on Thursday afternoon.

WOMEN'S PROGRAM

A luncheon and bridge party in addition to the luncheon with the men to be served during the trip to the Museum of Science and Industry is included among the activities scheduled for women visitors to the meeting. Sightseeing trips to the Field Museum, Shedd Aquarium, the Planetarium, and other points of interest, though not scheduled events, are recommended to women visitors. Local theatrical and musical events also are recommended.

ADVANCE REGISTRATION

Members who expect to attend the meeting are urged to register in advance by filling in and mailing the advance registration card which will accompany the mailed announcement of the meeting. This will assist the registration committee and save time on arrival. It is suggested that as many members as possible should make their plans to arrive on Sunday, November 2, as the registration desk will be open that afternoon. All members are requested to mention their attendance at the Midwest general meeting when writing to any Chicago hotel for reservations during the period of the meeting. Hotels have been notified and will give priority accordingly.

Future AIEE Meetings

Midwest General Meeting

Congress Hotel, Chicago, Ill., November 3–7, 1947

Winter General Meeting

William Penn Hotel, Pittsburgh, Pa., January 26–30, 1948

North Eastern District Meeting

New Haven, Conn., April 28–30, 1947

Summer General Meeting

Mexico, Federal District, Mexico, June 21–25, 1948

Pacific General Meeting Sets Attendance Record at San Diego

Since 1910 the AIEE Pacific District (number 8), the AIEE Northwest District (number 9), and the Vancouver Section of the Canadian District (number 10), have co-operated in the joint project of holding somewhere within their territory each year an AIEE general meeting. With the exception of 1917, 1918, 1933, and 1945, these meetings have been held annually, alternating among the sponsoring districts. Three times, in 1921, in 1936, and in 1939, the Pacific general meeting was not held separately, but was consolidated with the AIEE summer general meeting which was held on the Pacific Coast.

The San Diego Section (organized in January 1939) was host to the 1947 Pacific general meeting, with a program which drew a verified attendance of 589 persons, thereby establishing a new attendance record for the meeting. Runners up for attendance figures are the Seattle Section with 572 for the 1946 meeting, and the Los Angeles Section with 561 for the 1944 meeting. An analysis of the San Diego attendance, and a further comparison with other figures of recent years, are given in accompanying tabulations.

The far western Districts already are making plans for the 1948 Pacific general meeting to be held under the sponsorship of the Spokane Section, and the 1949 meeting under the sponsorship of the San Francisco Section. For 1950, present plans look hopefully toward the consolidation of the Pacific general meeting with the AIEE annual summer general meeting, under the sponsorship of the Los Angeles Section.

The San Diego meeting was opened officially by San Diego Section Chairman G. E. Jenner. G. E. Arnold, assistant city manager, extended San Diego's official welcome to AIEE, and AIEE Vice-President D. I. Cone of the Pacific District responded. Then President Blake D. Hull took over the chairmanship of the opening session to introduce W. F. Peterson (F '46) of the Los Angeles Section, design and construction engineer for the Los Angeles Department of Water and Power, who gave a comprehensive illustrated lecture embracing the "Important Engineering and Economics Features of the Proposed Colorado River Developments." Mr. Peterson described the Colorado River as "constituting the life blood of the Pacific Southwest," and stated that "the most important feature of this river is the ultimate scarcity of its water or its ultimate inability to supply the potential needs of the communities dependent upon it for irrigation and domestic water supply; the next feature of importance is . . . . the potential power capability of the river, and its relation to the power needs, of this same Pacific Southwest area."

Mr. Peterson discussed the characteristics of the Colorado River and the "broad potentialities of the Colorado River basin as presented in the preliminary comprehensive report on the Colorado River issued in March 1946 by the Bureau of Reclamation of the United States Department of the Interior." In addition to proposed hydroelectric power developments, long distance power transmission problems, and other "co-incidental economic problems of integration and power development," the speaker also gave particular attention to the Central Arizona Project now pending in Congress, and sought to clarify the policy questions currently at issue between the states of California and Arizona as to their respective water rights. It is expected that the essential substance of Mr. Peterson's presentation will be published in an early issue of *ELECTRICAL ENGINEERING.*

A luncheon meeting Wednesday noon

was the occasion for a second general assembly. presided over by C. F. Terrell of the Seattle Section, AIEE vice-president for the Northwest District. President Hull, as the feature speaker, addressed the assembly on the subject "Organization of an American Engineering Association." Mr. Hull outlined a practical plan which would enable the several national engineering professional societies to operate collectively on matters of common concern, in both local and national areas, without losing or interfering with their individual continuation and further development of technical activities in their several fields. Mr. Hull emphasized the fact that "professional recognition cannot precede, but may follow, professional unity."

TECHNICAL PROGRAM

In addition to the foregoing two general assemblies, there were 14 technical sessions, two of which were devoted to the presentation of student technical papers. These sessions accommodated the presentation and discussion of 16 regular technical program papers, 20 conference papers, and 7 papers at the student sessions. The sessions were held two in parallel, each morning and afternoon of the 3-day meeting with the exception of the opening morning. The subject matter of parallel sessions thoughtfully was arranged to provide for minimum conflict in audience interest. All sessions were well attended and discussion was active on most of the topics presented, so active and prolonged in fact that, in some sessions, the sessions ran over their allotted time. The procedure of scheduling no more than four topics for any one session, and only two or three topics for many of the sessions, proved to be a very popular arrangement, and apparently served to stimulate as well as to accommodate a wider range of audience participation and discussion than is possible where greater number of topics is scheduled.

The activities of these technical sessions are reported upon in some detail, elsewhere in the news pages of this issue (*pp 1016-24*). Many of the topics, including some of the conference presentations, are scheduled to be published in early issues of *ELECTRICAL ENGINEERING*, for the benefit of interested members unable to attend the Pacific general meeting in San Diego.

INSPECTION TRIPS

Five organized inspection trips had been prearranged by the local committee. These trips were interspersed with the meeting's program, one on Tuesday, two on Wednesday, and two on Friday. They included a United States Navy escort aircraft carrier, the Solar Aircraft Company, the Silver Gate steam-electric generating plant of the San Diego Gas and Electric Company, the huge aircraft factories of Consolidated Vultee Aircraft Corporation, and the United States Navy electronics laboratory located on Point Loma. These inspection trips were described in detail on pages 801–02 of the recent August issue of *ELECTRICAL ENGINEERING.*

SOCIAL ACTIVITIES

Principal feature of the generous entertainment program for both men and women was the "Night in Old Mexico," Wednesday evening, August 27. Most of those attending the meeting joined the general party for dinner at Serena's in Tijuana, Mexico, done in Mexican style. After dinner, the evening was spent enjoying the program of dancing and entertainment, taking in the greyhound races, or the fast Jai Alai games, or in informal sightseeing around the Mexican town. The second general activity which took in practically all of those registered was the two hour sightseeing boat ride around San Diego Bay, with luncheon served aboard. The third general feature was an informal banquet held Thursday evening in the Continental Room of the San Diego Hotel, where Doctor Albert W. Bellamy, professor of zoology at the University of California at Los Angeles, gave an informal address on the subject "The Biological Significance of the Bikini Tests," reflecting his own personal contacts with and observations of that significant experiment.

AIEE PROCEEDINGS

Order forms for AIEE *PROCEEDINGS*, and abstracts of the papers included, have been published in *ELECTRICAL ENGINEERING* as listed below. Each section of *PROCEEDINGS* contains the full formal text of a technical paper including discussion, if any, as it will appear in the annual volume of *TRANSACTIONS*. *PROCEEDINGS* are issued in accordance with the revised publication policy that became effective January 1947 (*EE, Dec '46, pp 576–8; Jan '47, pp 82–3*), and are available to AIEE Associates Members, and Fellows.

Meetings	Abstracts	PROCEEDINGS Order Forms
Winter	Jan '47, pp 84–93; Feb '47 pp 190–1	Feb '47, pp 33A and 34A
North Eastern District	Apr '47, pp 401–02	June '47, pp 55A and 56A
Summer General	June '47, pp 607–14; July '47, p 708	

Left to right: D. J. Cone (F '42) San Francisco Section, AIEE vice-president for 1947–49; N. B. Hinson (F '35) Los Angeles Section, AIEE vice-president for 1935–37; L. M. Klauber (F '23) San Diego Section

The relatively heavy proportion of women guests registered for the meeting generously were accommodated by additional events arranged especially for them. Highlight of the women's special program was the luncheon-bridge party Tuesday afternoon at the locally famous Imag Manor, a colorful place in the outskirts of San Diego, featuring smorgasbord meals, a courtyard swimming pool, and sumptuous club-like atmosphere. A 3-hour automobile sightseeing trip especially for the women included all of the outstanding historical and scenic points of the San Diego area, including the United States Naval Training Station, and the Old Spanish Lighthouse on Point Loma. The exceptionally large and well-stocked zoo was also a popular visit for the women.

A general sightseeing trip to the Palomar Observatory some 6,000 feet up in the mountains, east of San Diego, the site of the new 200-inch telescope of the Rockefeller Foundation (*EE Feb '42, pp 67–78*) was arranged as an all-day trip for Saturday, and attracted a large number of participants.

GOLF TOURNAMENT

Traditionally, the annual golf tournament in competition for the John B. Fisken Trophy is a fixed and predetermined part of the program for any AIEE Pacific general meeting. The recent meeting in San Diego was no exception, 26 players entering the tournament by virtue of making low net score for 18 holes of medal play. J. P. Price of the San Francisco Section won the Fisken Trophy, and with that honor the privilege of having his name engraved on the cup along with previous winners. He will retain the cup until it is put up again for competition at the Pacific general meeting in 1948 in Spokane. The coveted Fisken Trophy is a Pacific Coast institution, and is open for competition only to active members of the AIEE local Sections in the Pacific Northwest Districts and the Vancouver Section of the Canadian District.

In addition to winning the Fisken Trophy, Mr. Price won a valuable golf bag. Winners of other prizes included: H. S. Warren, of the Los Angeles Section, second low net score for 18 holes; H. D. Strong of the Los Angeles Section, third low net; E. W. Rockwell of the Los Angeles Section, first low gross; H. J. Wheeler of the Los Angeles Section, second low gross; F. L. Goss of the Los Angeles Section, third low gross; and B. B. Gravitt, consolation prize for high gross score. Winners had a rich collection of prizes from which to choose, in the order listed.

EXECUTIVE MEETINGS

Two executive luncheon conferences were held during the San Diego meeting, one a joint conference of Student Branch counselors and District officers under the chairmanship of Professor W. J. Warren, faculty counselor for the Student Branch at the University of Santa Clara, Calif. The other luncheon conference was an informal gathering of the District and Section officers of the Pacific District.

The Student Branch counselors for the Pacific District elected Professor W. G. Hoover, counselor for the AIEE Student Branch at Stamford University, as chairman of the Pacific District committee on student activities for the administrative year 1947–48.

The Student Branch counselors for the Northwest District elected Professor H. F. Lickey, counselor for the AIEE Student Branch at Washington State College, Pullman, Wash., as chairman of the Northwest District committee and student activities for 1947–48. This will give Professor Lickey the responsibility for the student activities at the 1948 Pacific general meeting in Spokane. This group agreed "that the Branches of the District 9 particularly need attention from national headquarters to see that speakers of note touring the region be scheduled occasionally to speak at Branch meetings," at least one such speaker per semester. Professor J. H. Johnson, counselor for the Student Branch at the University of Idaho, Moscow, retiring District chairman of student activities for the Northwest District, stated that the members of his committee "felt that the requirements for getting student papers considered for prizes needs clarification. Several schools thought their papers were being considered last year, as well as the year before, but found that their papers received no recognition even though they had been presented at meetings."

Vice-President D. I. Cone discussed student and other AIEE activities at the counselors' luncheon. In speaking of the desirability of extending and strengthening the student activities program of the Institute, including the activities and responsibilities and opportunities confronting the various Student Branches, he emphasized the desirability of developing future professional members of the AIEE through strong and constructive Student Branch programs in which individual students have opportunity for a wide range of active participation. In this connection, he emphasized very strongly the desirability of considering quality versus quantity in this development of future AIEE membership, that the Institute might be strengthened further by active and constructively interested new members who thereby would have even better opportunity of "earning for themselves a substantial reward through the personal satisfaction of active participation in a strong, constructive, and forward-looking professional electrical engineering organization." Mr. Cone emphasized the fact that AIEE is a mutual organization, and that an individual member should put something into the organization if he expects to get something out of it.

J. F. Sinnott (M '45) chairman of the AIEE general meeting committee

At the luncheon meeting of Section chairmen and District officers of the Pacific District, under the chairmanship of Vice-President D. I. Cone, general plans for District activities for the forthcoming year were discussed informally, the 1948 Pacific general meeting was confirmed for Spokane for probably the same relative week end as the San Diego meeting, confirmed tentatively the same week in 1949 for the Pacific general meeting in San Francisco, and laid specific plans for a formal meeting of the Pacific District executive committee in Los Angeles early in November 1947. Arizona Section representatives put in a tentative bid for the 1952 Pacific general meeting. Tentative plans were discussed looking toward the hopeful idea of organizing Pacific Coast subcommittees of AIEE national technical committees, especially in such subject fields as air transportation, power generation, and power transmission, which are of especial interest and major concern

Chairman C. J. Nevitt (A '33) San Diego, Calif., (left) presents the John B. Fisken Pacific Coast AIEE golf trophy to the 1947 winner: J. P. Price (A '45) of the San Francisco Section

Pacific General Meeting Attendance—1940–1947

Year	Location	Attendance
1947	San Diego, Calif.	589
1946	Seattle, Wash.	572
1945	no meeting held	
1944	Los Angeles, Calif.	561
1943	Salt Lake City, Utah	193
1942	Vancouver, B.C.	245
1941	Yellowstone Park	322
1940	Los Angeles, Calif.	465

Left to right: AIEE President Hull; G. E. Jenner (M '41) 1947–48 chairman, San Diego Section; AIEE Secretary H. H. Henline

B. B. Gravitt (A '36) vice-chairman of the AIEE general meeting committee

to the 11 western states. There was considerable discussion of the recent action of the California state legislature in modifying the act covering the licensing and registration of professional engineers, to include electrical and other engineers not previously covered. It was the general consensus that "a start has been made in the right direction," and that further revision and clarification would be desirable. In this discussion it was emphasized by AIEE Secretary Henline that AIEE national funds were restricted by organization charter and could not be made available for local Section participation in activities directly pertaining to legislation, but that there were neither inhibitions nor prohibitions which should interfere in any way with local AIEE members individually or collectively taking any action which they might deem to be desirable with reference to legislation effecting the status of the engineering profession.

The question of desirable scope for entertainment programs for Pacific general meetings came in for considerable discussion, especially with reference to the practice which has grown up within very recent years whereby the local Section which serves as host for the meeting has been underwriting a cocktail-party reception for the free participation of all meeting registrants. This activity, born during the free-spending cost-plus days of the recent war period, has grown to such proportions that it constitutes a major expense item in the budget of the general meeting, sometimes equaling all other expenses put together. The discussion brought out the fact that the unanimous opinion was that this particular item in the entertainment program be recommended specifically for omission from the programs of future Pacific general meetings. Incidental to the discussion of this subject, the point also was brought out strongly that the activities of such meetings should be self-sustaining so that any necessary underwriting by the host Section would be reduced to such a nominal amount that no canvassing of funds from outside sources would be necessary, as such canvassing is contrary to AIEE traditional policy and practice.

Analysis of Registration at 1947 Pacific General Meeting

Classification	Dist 8	Dist 1	Dist 2	Dist 3	Dist 4	Dist 5	Dist 6	Dist 7	Dist 9	Dist 10	Foreign	Totals
Members	275		8	4	1	1	3	1	19			312
Men guests	109	2	3	1	2				2		1	120
Women guests	124		2				2	1	5			134
Student members	18					5						23
	526	2	13	5	3	6	5	2	26		1	589

WHO DID THE WORK?

Because of the failure of other plans of the Pacific District with reference to the recent general meeting in San Diego, it was not until January of 1947 that the San Diego Section assumed the responsibility of organizing and presenting the 1947 Pacific general meeting in San Diego. The meeting was eminently successful from all points of view, and thoroughly enjoyed by its participants if one may be guided by the informal comments frankly voiced in the hotel lobbies. The people directly responsible for the operating details of the San Diego meeting were the following:

General Committee

J. F. Sinnott, *chairman*
B. B. Gravitt, *vice-chairman*
R. T. Strong, *treasurer*
W. J. Kenline, *secretary*

Technical Committee

C. J. Breitwieser, *chairman;* W. L. Bryant, *vice-chairman;* C. W. Terrell; J. F. Hesse; E. B. Kipp; R. T. Adamson; R. E. Johnson; H. L. Rorden; W. N. Lindblad; W. P. Bustard; D. R. Hoopes.

Hotel and Registration Committee

J. P. Conner, *chairman;* G. E. Jenner, *vice-chairman;* E. C. Fremo; R. W. Piper; J. H. Way; G. D. Shermerhorn; E. C. Rogness; E. B. Love; F. J. Groat; M. M. Bridgwater; R. V. Davis.

Arrangements Committee

O. L. Doolittle, *chairman;* P. E. Roosenburg, *vice-chairman;* D. H. Caton; D. C. Bertrand; G. B. Kenline; E. F. Kotnick; O. K. Wahrenbrock; C. R. Smith.

Entertainment Committee

I. E. McDougal, *chairman;* E. M. Foster, *vice-chairman;* E. B. Kipp; W. J. Beran; D. B. Allabough; C. M. Hart.

Finance Committee

H. A. Cordes, *chairman;* F. F. Evenson, *vice-chairman;* L. M. Klauber; R. T. Strong; C. F. McCabe.

Student Activities Committee

S Rogers, *chairman;* K. Abbey, *vice-chairman;* F. W. Schott: C. D Mack; J. C. Clark.

Publicity Committee

P M Klauber, *chairman;* R. V. Davis, *vice-chairman;* N Pike; C. A. Poppino; D. A. Riechel; F. W. Morris; R. Bollaert; J. A. McDonald.

Golf Committee

C. J. Nevitt, *chairman;* H. A. Cordes, *vice-chairman;* A. S. Glasgow; W. E. Lee; J. C. Hinkle; F. L. Goss; O. A. Gustafson.

Transportation and Inspection Trips

E. H. Templeton, *chairman;* R. Bennett, *vice-chairman;* J. B. Bowen; A. H. Keith; B. A. Murray; N. W. Lenten.

Ladies Committee

Mrs. H. A. Cordes, *chairman;* Mrs. J. F. Sinnott; Mrs. B. B. Gravitt; Mrs. R. T. Strong; Mrs. W. J. Kenline; Mrs. J. P. Conner; Mrs. J. M. Bowen.

Miscellaneous Subjects at First Technical Session

F. F. Evenson (M '29) consulting engineer, San Diego, Calif., presided at session on selected subjects on Tuesday afternoon, at which three conference-type papers were presented.

The broad subject of "Energy Dynamics of the Electromagnetic Field," was discussed by R. H. Dishington (A '43) and B. G. King of the electrical engineering faculty of the University of Southern

California, Los Angeles, attacked the problem of choosing a "medium" for the electromagnetic field by defining energy itself as that medium. On this basis they find, then, that "matter and the fields are configurations of the medium, energy." Inasmuch as energy never has been defined physically before, it is described as a "continuous infinitely compressible fluid." Then space is filled with a fluid, energy, which is concentrated greatly at some points, greatly rarified at others, and always in a state of change. Postulating the point-source of energy flow as an electron, it is seen immediately that no actual "matter" exists in the electron. Thus its "mass" is only electrodynamic and is zero at rest. If energy flow and density are reversed, a point-sink is produced which has all the properties of a positron. As a further conjecture, these two are considered to be the only basic particles, and protons, neutrons, and other particles are regarded as being only complex structures containing these basic particles.

The authors stated in conclusion that "no force equation, either static or dynamic, can be derived classically because the true energy fields during acceleration are unknown in the classical system whereas in the proposed new system force is shown to have no meaning. Actions and reactions take place because of the difference in actual energy density in space. Until mathematicians supply a new mathematics to solve energy field equations no derivation of force-produced acceleration fields can be made."

In discussing "The Analysis of Retarded Control Systems," L. A. Pipes (A '37) of the Hughes Aircraft Company, Culver City, Calif., presented a mathematical analysis of control systems of the closed-cycle type, the action of which is such that the control mechanism introduces appreciable time lag. The discussion was presented in general terms and was applicable to the analysis of devices for the automatic steering of ships, piloting of airplanes, controlling of speed, maintenance of constant pressure or temperature, and other similar actions.

The introduction of a time lag in the dynamical equation of a control system leads to a linear differential equation of infinite order. This equation is solved by the use of modern operational or Laplacian transform methods. The solution is obtained in closed form for any value of the time parameter. The question of the stability of systems involving retarded action is studied by the use of the complex variable in a similar manner to that used by Nyquist in studying the stability of feed-back amplifiers. The author states that, "This rigorous method of studying stability reveals the fact that erroneous conclusions have been obtained in the past by some investigators who have analyzed the problem by approximate methods."

The experimental development of a war-time fire-control principle, "A Derivative-Computing Servomechanism for Power Governing," was described by T. E. Curtis (A '40) assistant engineer, Pacific Gas and Electric Company, San Francisco, Calif. The technical literature bears out that the ideal power system governor requires co-ordinated response to load, frequency, time, and relative proximity to load. In general, present governing systems have primary sensitivity only to frequency (speed), and response to other conditions is obtained through supplementary control. The author considers "the attractive possibility that the art of servomechanisms can provide a single integrated instrument which can operate a conventional governor to yield primary sensitivity to load, frequency, time, and proximity to load," and do this without dependence upon load telemetering channels.

This governing system is based upon a derivative-computing servomechanism which continuously computes ϕ, $d\phi/dt$, and $d^2\phi/dt^2$, where ϕ is the electrical phase angle between the power system and a primary frequency standard. Tests of this servomechanism appear to substantiate its potential use in power system governing.

Variety of Topics Presented at Student Sessions in San Diego

Two sessions of the Pacific general meeting in San Diego were devoted to the presentation and discussion of eight papers by Student Members. One of these sessions was presided over by Professor W. J. Warren (M '46) counselor of the Student Branch at the University of Santa Clara, Calif., and chairman of the Pacific District committee on student activities. The other session was presided over by Professor W. G. Hoover (A '34) counselor of the Student Branch at Leland Stanford University, Palo Alto, Calif. The following digests of these student papers were prepared for *ELECTRICAL ENGINEERING* by these two session chairmen.

The investigation "Protection of a D-C Shunt Motor upon Loss of Field Excitation," by Francis Mezzatesta (Student Member) and read by James Roth, a first year graduate student, both students of the University of Southern California, Los Angeles, describes a circuit to supplement the customary "4-point" manual d-c motor starter to provide for loss of field excitation. It will be remembered that this type of starting box has its holding coil connected across the line thereby serving as an undervoltage release. Should the field circuit become open, however, there is normally no provision to cut power to the motor to prevent excessive increase of speed.

The device tested is a resistive-inductive-capacitive circuit used in conjunction with the motor field circuit. Motor field current flowing through a suitable low resistance develops a voltage to charge a capacitor through the inductance of a relay with the parameters chosen so the circuit is overdamped. When the field circuit is opened suddenly the capacitor discharges through the relay causing its contacts, which are in series with the starting box holding coil, to open. Therefore, the loss of field excitation is attended by removal of armature power to the motor.

The circuit was analyzed by the usual differential equations; specific values were determined for an assigned degree of damping in a given motor field circuit. It was found that interruption of the highly inductive field circuit current caused behavior different than predicted. Shunting the motor field circuit with a capacitor served to overcome this difficulty. Satisfactory performance ultimately was realized on 7.5- and 18.5-horsepower 250-volt d-c motors.

Direct and indirect methods of obtaining the speed–torque curve of an induction motor were listed in "Acceleration Test of An Induction Motor" by J. Drake, master of science from the California Institute of Technology, Pasadena. These methods involved laborious procedure to obtain point-by-point data and often result in serious heating of the machine under test.

Since the rate of change of motor speed is acceleration, it follows that with a load of constant rotational inertia (including motor rotor inertia) the torque developed by the unloaded motor is at all times proportional to its rate of change of speed.

The paper described a series resistive-capacitive circuit with the parameters so proportioned that the voltage appearing across the resistance was proportioned to the rate of change of the voltage applied to the series combination. This voltage was proportional to the speed of the motor under test; being obtained by rectification of the output voltage of a polyphase tachometer generator connected to the motor. To filter suitably the rectified voltage, inductances (chokes) and an auxiliary capacitor were introduced. These inductances and capacitor were chosen of suitable magnitude to retain the fundamental resistive–capacitive behavior.

Oscillograms of speed–torque curves obtained by use of this differentiating circuit agree very well with the curves obtained by a point-by-point method. Irregularities in the speed–torque curves stemming from the manner in which the starting and running windings were connected were explained.

The differentiating circuit described lends itself to simpler presentation of the speed–torque data. It is possible to use d-c indicating meters for observing the speed and acceleration voltages. For production testing it would be possible to use visual "go" and "no-go" indicators operating from these voltages. The motor under test is not subject to prolonged heating and data are obtained very readily.

In "A 4-Terminal D-C Amplifier" by B. Lecanthi, who recently received a bachelor of science degree in physics and is now a member of the research staff at California Institute of Technology, Pasadena, some typical analogue computer circuits were shown pointing out the need for a 4-terminal d-c amplifier. While not so stated, it is known that a conventional vacuum tube will require specially arranged power supplies for use in a 4-terminal amplifier.

The solution advanced makes use of a magnetron-type tube. The vacuum-enclosed envelope contains the usual single wire filament coaxial with the anode cylinder. A substantially uniform axial magnetic field is provided by a cylindrical alnico permanent magnet with end plates which fits loosely over the glass envelope allowing for a 1,000-turn coil wound closely over the glass envelope and fitted with an electrostatic shield. The field of this coil is colinear with that of the permanent magnet. An alternating or direct current in the coil produces a corresponding variation of electron flow to the anode. By choice of plate load resistance the dynamic characteristic, relating output voltage developed across this resistance and current in the deflecting coil, is nearly linear. It is expected that output voltages up to three volts with as little as two per cent harmonic distortion can be realized.

Test results on a unique type of magnetic deflection tube made by John R. Pierce of the Bell Telephone Laboratories, Inc., New York, N. Y., were described. This tube uses crossed magnetic fields; one used for focusing an electron beam from a narrow cathode spot, the other for deflecting this electron beam to permit varying electrons of the beam to pass over a barrier plate to a collecting anode. The tests revealed a very desirable dynamic characteristic for low values of the plate load resistance but an undesirable characteristic for high values of the plate load resistance.

Data presented in "Abnormal Characteristics of the *FG-67* Thyratron Tube" by C. L. Johnston and presented by Gerald Hattrup, senior student at the University of Idaho, Moscow, show that the normal control characteristic (curves of plate voltage versus grid voltage at "firing") will vary widely with ambient temperature. The shape of this curve also changes markedly with temperature.

The data presented are substantially in agreement with those reported by Robert Gibson of the University of Illinois, Urbana, in a master's thesis submitted in 1934. Mr. Johnston suggests some possible basis for these abnormalities. The variation of the relative position of the control characteristic with ambient temperature is ascribed to variation of sparking potential of a gas with the product of pressure times distance between electrodes; that is, Poisson's Law. The irregular shape of the control characteristic at certain ambient temperatures in the neighborhood of 70 degrees centigrade is ascribed to the manner in which the probability of collision of gas particles (or electrons and gas particles) varies with the velocity of the particles.

"Effects of Very High Temperatures on Transformer Core Loss" by W. R. Singletary and J. H. Capps (Student Member) both of Oregon State College, Corvallis, who now are graduated but who were seniors when the work described was done (1946–1947), was presented by B. H. Beam (Student Member) senior student in electrical engineering at Oregon State. Development of silicone insulation allows use of considerably higher operating temperatures which in turn makes important knowledge of effects of high temperatures on losses in magnetic materials possible.

Tests on a specially insulated $17^1/_2$-kva test transformer were described. Measurements were made of temperature rise of windings, hysteresis loops for the iron were observed, and core loss was measured. Core loss decreased about 11 per cent from room temperature to 470 degrees centigrade. Exciting current rose nearly 70 per cent over the same temperature range. An average decrease in permeability was observed with constant flux density maintained during the tests. The conclusion was that with adequate high-temperature insulation, operation at around 250 degrees centigrade seems feasible, but that high copper losses are to be expected.

"Adaptation of a Military Amplidyne to Machine Laboratory Experiments" by J. A. Scaroni (Student Member) senior at the University of Santa Clara, Calif., described the availability of surplus military amplidynes and the importance of the amplidyne in control which makes desirable the use of such a device in university laboratory instruction. Three senior students adapted such a device for various experiments in the laboratory, and experimental measurements of output voltage as a function of load current were made and compared with calculated performance. Application of an amplidyne-controlled exciter to furnish field current for an a-c generator was described in which regulation of less than 1 volt out of 220 volts occurred with change of load from 0 to 150 per cent of full load.

"Should Teachers Be Taught?" by DeForest L. Trautman, Jr., (A'45) graduate student in electrical engineering at Leland Stanford University, Palo Alto, Calif. focused attention on teaching aspects of engineering, and examined present methods of teaching from the viewpoint of prospective engineering teachers. The questions were asked "Should teachers be taught?" and then "What should teachers be taught?"

The engineer of the future needs development in technical knowledge with emphasis on fundamentals, and skills in communication so that the engineer may be able to express himself in his own and in other fields. Emphasis can be placed on seminar speeches and reports in school. Also, the engineer must be conscious of the significance of his work socially. Since the time spent in school has such an important bearing on attitudes in later life it is very important to obtain effective teaching. Teachers need preparation for teaching as well as scientific training. This includes a "kit of tools in communicating ideas," and courses in higher education.

"An Electronic Reflector Voltage Tracking Circuit for Reflex Klystron Oscillator" by John F. Honey, graduate student in electrical engineering at Leland Stanford University, reported work on the development of a local oscillator for high-frequency receivers in which the reflex klystron is very important. As the frequency of oscillation is changed by tuning the receiver, the klystron reflector voltage must be changed in such a manner as to maintain the desired oscillation. It is very desirable to have this result produced automatically so that one less receiver adjustment is necessary.

A circuit for producing this automatic adjustment was presented as follows:

1. The reflector voltage is modulated by a small 60-cycle voltage.
2. The reflector d-c voltage is supplied from the output of a d-c amplifier.
3. A small portion of the radio-frequency energy in the klystron cavity is rectified and combined with a reference 60-cycle voltage at the amplifier input in such a manner as to tend to maintain a maximum level of oscillation. Frequency modulation of the radio-frequency output practically is eliminated by compensating modulation of the cathode voltage in the klystron.

Power Important in Discussions at Aircraft Sessions on Wednesday

H. F. Rempt (A'43) group engineer, electrical staff engineering, Lockheed Aircraft Corporation, Burbank, Calif., presided over both the morning and afternoon aircraft sessions on Wednesday, August 27. His assistance in the preparation of the following report of this session is acknowledged.

"D-C Aircraft Generator Power Center," a technical program paper by E. L. Bottemiller of the General Electric Company, Schenectady, N. Y., described an aircraft generator power center consisting of generator voltage regulator, generator control relay, reverse current circuit breaker, and circuit protective circuit breakers built into one draw-out unit which can be replaced by lifting a latch and withdrawing the unit thus breaking all power and control circuits. The power center was developed to meet a need in commercial aircraft for a centralized grouping of all control and protection for the aircraft generator. Previously these devices were mounted individually at various locations throughout the airplane, and were wired together with a maze of cables.

"A New Approach to an Integrated Power Generating System for Aircraft" by G. W. Almassy (A'43) General Electric Company, Los Angeles, Calif., listed the following types of operational functions and protection a modern generating system must have to be complete.

1. Normal operation must be entirely automatic—no generator can be allowed to affect adversely the output of another.
2. Reverse current protection against field circuit or reverse current relay failures.
3. Generator lead protection which removes from the bus, de-energizes, and isolates the faulted circuit.
4. Overvoltage protection.
5. Overload protection in the form of indicating light.

Present methods were discussed and evaluated. A new design was presented which was based upon the following points of basic design philosophy:

1. All emergency conditions within a single generator control circuit should be handled by a single piece of emergency standby apparatus—a high-current capacity and high-voltage capacity circuit breaker.
2. The energies released by a faulted condition should be used to control that fault.
3. Protection should be complete for the system, the airframe, and the apparatus.

The design accomplishes the following basic types of protection:

1. A more complete automatic switching arrangement which eliminates reduction in bus voltage due to an underspeeded generator.
2. Complete generator lead protection with differential current protection sensing series field and reverse current circuit breaker currents (the circuit breaker—next to the bus and with auxiliary contacts in field and equalizer circuits—is tripped for this and all other fault conditions), and reverse current protection in the form of the reverse current circuit breaker.
3. Complete system protection for any fault in a particular generator circuit trips its circuit breaker and thus isolates and de-energizes the faulted generator or control, or both.
4. Overvoltage protection, which operates on bus voltage, selects the generator causing overvoltage, and operates to isolate and de-energizes this bad generator without interfering with the other generators on the bus.
5. Overload protection in form of an indicating light.

"Automatic Temperature Control for Transport Airplanes," a technical program paper by R. E. Hedges (A '44) engineering department, Douglas Aircraft Company, Santa Monica, Calif., described the *DC-6* air conditioning system, which is one of the latest developments for obtaining maximum comfort to passengers and crew of transport airplanes. Operation of the system is fully automatic and requires no attention after an initial setting prior to flight. The cabin pressurizing system utilizes two engine-driven superchargers, which are capable of supplying fresh air through the cabin at 70 degrees Fahrenheit for a cabin altitude of 8,000 feet when the airplane is at an altitude of 20,000 feet. The cabin temperature control system conditions all air prior to its entering the cabin, and the control is designed to permit maintenance of selected temperatures between 65 and 85 degrees Fahrenheit.

At the afternoon aircraft session on Wednesday, J. A. Aldrich and J. R. Grace of United Air Lines, Inc., South San Francisco, Calif., presented a conference paper, "Engineering Maintenance of Aircraft Electric Systems." The electric systems in modern commercial aircraft have grown tremendously in capacity and complexity, and they have become more and more vital to the proper functioning of the aircraft. Wartime requirements brought many important advances in the development of units and systems, but also brought new problems. A much higher degree of reliability must be obtained from the standpoint not only of safety, but of schedule maintenance. Greater service life is expected from the units, and features for easy access for servicing, or quick removability for replacement, become of utmost importance.

For the guidance of equipment manufacturers, the author emphasized the need for:

1. Getting units and systems tested under actual operating conditions before manufacturers offer them for general use.
2. A more realistic appraisal of the operator's problems as they relate to the manufacturer's development of designs.
3. Placing added emphasis on releasing all manner of technical information and overhaul and maintenance instructions to users before equipment is put in service.
4. The design and production of test equipment for speedy line servicing and comprehensive shop overhauling of aircraft equipment.

In the ensuing discussion John Maxian (M '43) North American Aviation, Inc., Inglewood, Calif., asked, "The Civil Aeronautics Authority requires aircraft and engine mechanics' licenses but has no requirements for electricians—do United Air Lines do anything about that problem?" Mr. Aldrich replied that they require a second class radio operator's license for their radio and electronic technicians. S. D. Summers (A '37) Naval Research Laboratory, Washington, D. C., asked, "What kind of training do you require for new men?" to which it was answered that at present United Air Lines are having 3-month training periods on the *DC-6* airplane systems.

"Electrical Prerotation of Landing Gear Wheels," a conference paper by J. H. Keyser, Jr., (A '41) research analyst, Lockheed Aircraft Corporation, Burbank, Calif., described a prerotation device for reducing the magnitude of forces produced in landing gear and structure due to the very rapid acceleration of high-inertia landing wheels upon landing. Speed-torque characteristics required of a prerotation motor can be determined from the measureable wheel friction, the calculable acceleration torques, and the effect of the air loads which can be observed in preliminary flights or wind-tunnel tests. Wide variations in wheel friction and air loads are possible which necessitates use of a motor with good speed regulation. Special consideration must be given to the ventilation and heat capacity of a prerotation motor, and a prerotation motor is larger than a conventional motor of the same horsepower ratings. An electric prerotation motor has been developed for the Lockheed *Constitution* airplane, whose ring-wound armature is integral with the wheel and whose field mounts directly on the axle.

Discussion followed in which Mr. Aldrich of United Air Lines asked about the effect of the brake heat on the motor, to which the reply was given that so far no problems from this heat have arisen. Mr. Maxian of North American Aviation questioned the effect of dust and dirt and brake shoe material on the motor. Mr. Keyser replied that the motor is so mounted that the brake housing and the wheel completely enclose the motor. M. C. Clark of Lockheed Aircraft Corporation, asked about the relative merits of series, shunt, and compound motors for this application. Mr. Keyser replied that the series motor has too small a range of torque for the speed change during acceleration, and that the opposite is true of the shunt motor—therefore the compound motor was chosen.

After the recess S. D. Summers, chairman of the air transportation committee, spoke on the problems of the committee and how best to get better West Coast participation.

"Capacitance Fuel Gauges," a technical program paper by M. C. Clark and M. H. Adolphe (A '40) of Lockheed Aircraft Corporation, Burbank, Calif., described five models of gauges. Previous to the development of capacitance-type fuel gauges the quantity of gasoline in airplane fuel cells was measured volumetrically. Such measurement is misleading because the energy provided by the fuel depends directly on its mass rather than on its volume which changes with temperature. A capacitance-type fuel gauge consists of a stationary electric capacitor partially immersed in the fuel, a remote indicating capacitance meter, and the necessary associated equipment. Although the popular conception of saving in fuel loads by making the fuel gauge exceptionally accurate are erroneous, there are other reasons for requiring an accurate gauge, particularly in increasing the safety of long range flights by more precise determination of fuel remaining.

In the discussion of the paper, Carl Anderson of the Minneapolis-Honeywell Regulator Company, Minn., felt that too much emphasis had been placed upon temperature errors of the gauges when other errors that cannot be controlled exist and are very much larger. He said that in discussing the problems of temperature compensation with operators they did not believe the extra weight and complexity were justified. He also mentioned that small capacitance as used in the equation for error was not always a constant. Mr. Clark admitted this and added that it was considered a constant during the tests which were concerned mainly with temperature variations.

Marine Sound Equipment Discussed at Sonar Symposiums

H. A. Affel (F '41) director, transmission development department, Bell Telephone Laboratories, Inc., New York, N. Y., presided over the two sessions on sound navigation and ranging (sonar) held Friday, August 29.

Captain Rawson Bennett (M '45) United States Navy, Navy Electronics Laboratory, San Diego, Calif., outlined briefly the history of the development of sound navigation and ranging equipment as a military weapon with some attention to the commercial uses of such equipment in a conference paper, "General Survey of Sonar Development." The paper covered the period from World War I to World War II and served as an introduction to the subject for those not familiar with that portion of electron art. The paper was followed by a movie, "Underwater Sound."

The bearing deviation indicator, a war development that greatly increased the effectiveness of sonar equipment in antisubmarine warfare, was described in "Improving Sonar Accuracy With the Bearing Deviation Indicator," a technical program paper by O. H. Schuck (M '41) research department, Minneapolis-Honeywell Regulator Company, Minn.; C. K. Stedman, Boeing Aircraft Company, Seattle, Wash.; J. L. Hathaway, National Broadcasting Company, New York, N. Y.; and A. N. Butz, Jr., (deceased) (A '45) formerly of the Ordnance Research Laboratory, Pennsylvania State College, State College. To eliminate the shortcomings of World War I underwater listening equipment, echo ranging sound equipment was developed, and reached a high degree of perfection before World War II began. It was evident, however, that accuracy of bearing information left much to be desired. The great width of the beam, length of interval between successive pulses, and the bearing frequently changing quite rapidly because of relative motion of the target and the detecting vessels was sufficient to impair the usefulness of the sound equipment seriously. The most obvious expedient was to use a sharper beam.

An experiment was tried first in 1941 using two transducers for angular discrimination by lobe comparison but accuracy and speed were little if any better than with a single beam. Finally a circular transducer divided in half electrically along a vertical diameter was adopted. The two halves are connected together for transmission of a sound pulse so that the normal directivity pattern is obtained. For reception the electric signals from the two halves are supplied simultaneously to two directive networks connected in parallel. In each network signals from the two halves are shifted in phase so that the directivity pattern is altered in the desired manner. The indicated bearing deviation is measured by the difference in response from the left-shifted and right-shifted pattern. The simultaneous lobe comparison principle was the system most widely used in echo ranging bearing deviation indicator equipment manufactured during World War II. As a further improvement in the instrument, a cathode-ray tube could be used to indicate directly the difference between two signals and so eliminate dependence on the human ear which is notoriously poor for accurate comparison of sound intensity. Time-varied gain, reverberation-control gain, and Own-Doppler nullification were discussed. Mention was made of specialized test equipment.

"Submarine Detection by Sonar," a technical program paper by A. C. Keller of Bell Telephone Laboratories, Inc., New York, N. Y., was presented.

"The Application of Sonar to Harbor Defense and Amphibious Landing Operations," a conference paper by Elias Klein and C. F. Jones of the Naval Research Laboratory, Washington, D. C., described two sonar systems developed to serve entirely different needs of the Armed Forces. One of them guarded the entrances to harbors against sneak attacks by enemy submarines; the other guided landing parties in amphibious operations to a preselected beachhead. Both equipments are characterized by the emission of ultrasonic signals from a relatively fixed underwater transducer. The harbor protective equipment consisted of two distinct installations, a shore station and a sea station. The electroacoustic sea station transducer of the harbor unit detected either by listening to noises generated by vessels' engines and propellors or by echo ranging. Accurate information on the bearing and range of the intruder was obtained by the shore station through remote control of the ultrasonic beam of the sea station.

The ultrasonic underwater beacon for guiding landing parties was planted in advance to mark a spot on the enemy's beach where it was submerged and anchored off shore. A transducer or hydrophone in the leading landing boat enabled the listener to hear a prearranged underwater coded signal from the ultrasonic beacon. Certain unique features such as a time delay and program motor, an automatic self-destruction device, and a sea-activated battery had to be developed to satisfy the strategic and operational requirements of the equipment.

Facilities which must be available to measure sound levels, voltage, current, power, complex impedance, sound level as a function of direction, and integrated sound energy at all frequencies between ten cycles and one megacycle were described in "The Instrumentation and Techniques of a Sonar Calibration Station," a conference paper by Cecil Burbank of the Naval Electronics Laboratory, San Diego, Calif. Equipment was mounted on a barge and included a heterodyne frequency analyzer, power level recorder, filters, integrating wattmeters, polar recorders, and associated measuring equipment. In the determination of standard sound levels a transceiver is used to establish a sound field at a hydrophone. Current into the transceiver for the output voltage of the hydrophone is recorded, then the transceiver is replaced by the source unit and the input power adjusted to give the same output from the hydrophone as was obtained in the previous run. If sufficient care is used to insure a sensibly free field and to be certain that the electrical measurements are accurate, a known sound field can be established from a knowledge of the current, voltage, frequency, and distance involved.

"Echo Repeater Practice Target for Training Sonar Operators," a conference paper by Gene G. Reed (A '38) and W. L. Bryant (M '37) both of the Navy Electronics Laboratories, San Diego, Calif., described a sonar practice target which must be the equivalent of the reflective area of the hull of a submarine. Devices called echo repeaters comprise a high-gain electronic amplifier and two transducers, one working as a hydrophone to pick up the detecting signal, and the other as a projector of the amplified echo signal. Characteristics of the return signal or echo are a true reproduction of the original in frequency, duration, and relative amplitude. To provide realistic training, one model was towed at a depth of 60 to 90 feet, 1,200 feet astern of the tow craft.

Three Power Sessions at Meeting Feature Number of Varied Topics

The first of the power sessions held on the morning of Wednesday, August 27, was presided over by C. F. Terrell (M '46) vice-president, Puget Sound Power and Light Company, Seattle, Wash. The second power session, held Friday morning, also was presided over by Mr. Terrell. The third power session, Friday afternoon, was presided over by AIEE Past-President R. W. Sorenson, head of the electrical engineering department, California Institute of Technology, Pasadena.

"A Simple and Inexpensive Method for Accurately Measuring Steady State and Transient Voltage on High Voltages," a technical program paper by H. L. Levinton (M '45) electrical engineer, Bonneville Power Administration, Portland, Oreg., describes a method of measurement which does not modify the conditions producing the voltage to be measured. An economical electronic "amplifier" made of radio parts and having high input resistance and a negligible circuit loading provides adequate current to operate magnetic oscillograph galvanometers (also meters or relays) in proportion to the input voltage obtained from capacitance voltage dividers. Frequencies ranging from direct current to 100 or more kilocycles are within the capability of the device.

"Conductor Vibration Studies on Energized 230-Kv Transmission Lines" by M. G. Poland (A '46) and M. B. Elton of the Bonneville Power Administration, Portland, Oreg., was a conference paper which presented a condensed review of some of the more important considerations necessary in the study of conductor vibration, fatigue damage, and remedial measures. The authors also reported in some detail the methods and equipment used in testing various sections of the Bonneville transmission system to determine needs for vibration dampers. This included methods of making installations on energized 230-kv lines with glass twine having a high dielectric strength. One novelty reported was the combination of vibration records with wind velocity and direction data on the same charts. Wax-coated charts were used to obviate the troubles inherent in the use of ink curve-drawing instruments for such purposes. In general the authors' findings were in conformity with data previously published by AIEE and others.

"The Design and Performance of the Vertical Generator Thrust Bearings at the Bonneville Plant of the Corps of Engineers—War Department" by F. M. Lewis (F '44) senior engineer, United States Engineers, War Department, Bonneville, Oreg., and T. W. Gordon of the General Electric Company, Schenectady, N. Y., described the largest water wheel generator thrust bearings in the world. Loading on these bearings was reported to be in excess of 1,500 tons. The bearings are 112 inches in diameter, the rotating plate weighs 6 tons, and the stationary plate weighs 3 tons. To simplify the handling problem, the designers cut the rotating plate into segments each weighing a maximum of 1,000 pounds, the segments being keyed to the rotor hub by means of "T" keys. The Bonneville project consists of two 48,000-kva units and ten 60,000-kva units, all at 75 rpm, and all of the vertical shaft hydraulic turbine type with direct-connected main and pilot exciters mounted on top. Operation of the initial bearing pointed out a looseness of runner segments, that grooves in the runner plates rotating over the babbitt shoes produced a force which caused fretting corrosion, and that iron oxide escaped from its generating surfaces through the openings between the runner segments directly downward to the babbitted surfaces. Since adoption of the final bearing design there have been a total of nine cases of bearing wiping in nine years of station operation at Bonneville. Recent inspections of the bearings give every indication that successful operation will continue.

In the discussion which followed the paper presented by Lewis and Gordon, A. B. Lakey, chief engineer, Kingsbury Machine Works, Inc., Philadelphia, Pa., listed objectives envisioned in an ideal bearing. The characteristics of an ideal bearing would be

1. One hundred per cent availability and reliability, usable for indefinite periods without need for maintenance attention.

2. Remain undamaged indefinitely from any operating cause including creeping at low speed due to gate leakage, slow starting, heavy or full loading at starting, any kind of starting or stopping, destructive friction, and fatigue of any parts.

3. Conservation of revenue kilovolt-amperes; that is, reduced friction.

4. Minimum need for and use of auxiliary equipment such as high pressure oil pumping and piping systems, whether their purpose be lubrication or jacking.

5. Avoidance of mechanical vibration.

6. Avoidance of the setting up of kneading, massaging, galling, and fretting action of traveling loads, as in the parts supporting the bearings or in its connections to the shafts; that is, the bearings should be truly self-aligning despite subsidence or growth of concrete settings, or earth movement and readjustment.

In a conference paper, "Electrolytic Cleaning of Rectifier Tanks," C. K. Ittner (A '45) electrical engineer, Aluminum Company of America, Troutdale, Oreg., described the nonconventional but successful chemical methods developed for economical cleaning of tanks without hazard to workmen. The disassembled rectifier tank first is treated for 30 minutes with a boiling solution of Oakite number *30* powder, $2^{1}/_{2}$ gallons of powder to 55 gallons of distilled water. For the second step a 47 per cent (by volume) acid solution of Oakite number *32* at a temperature of about 65 degrees centigrade is used, with an iron pipe immersed to serve as a negative electrode, for a 13-minute electrolyte treatment at 450 amperes of direct current. Flushing, drying, degassing, and reassembly complete the operation. The result is reported as being a cleaner tank with less man-hours than the traditional manual wire-brushing, and complete absence of the serious personnel hazard of accumulative mercurial poisoning.

"Circuit Breaker Current Measurement During Reignitions and Recovery," a technical program paper by L. J. Lewis (A '36) electrical engineering department, University of Washington, Seattle, pointed out that considerable attention has been given to the importance of transient recovery voltage across the terminals of a circuit breaker as a factor in arc extinction. A circuit containing a continually lengthening a-c arc, where current reverses each half-cycle and where the voltage across the arc space increases rapidly following each reversal, the amount of current flow is a measure of the arc conductivity during the critical period; the magnitude of the current during a short interval may serve to indicate how closely the circuit breaker comes to interrupting the circuit. Also important is the effect the current has on the form of the recovery voltage; it is evident that arc conductivity introduces into the circuit a factor of variable resistance, which, combined with other circuit parameters and generator voltages, determines the transient voltage across the arc space. An investigation recently was undertaken to determine if current measurements of higher sensitivity could be made during each of the critical periods. Special attention was given to protecting the current measuring circuits from influence of high voltage in the test circuit. The study indicated that current during recovery may have a pronounced effect on recovery voltages; in the present study, the effects of the current were such that in a period followed by reignition, at no time did the recovery voltage reach a value equal to the generator voltage. Whether the current has as much effect in high-power tests at high voltages on modern high-speed circuit breakers, still remains an open question.

"Symposium on Distribution System Modernization," a conference paper by H. E. Jung (A '43) and R. C. Blankenburg (M '46) both of Southern California Edison Company, Ltd., Los Angeles, was followed by discussion by the following power companies of the California Electric Power Company: Burbank, Glendale, Pasadena, and San Diego-

The objective of any distribution system is to give the ultimate consumer the greatest possible amount of the best product with the least cost to the consumer consistent with the cost of production. The intangible product dispensed by the electric distribution system has been called "service," and adequate service should be the objective of distribution system in giving continuity of service, supplying proper voltage, proper frequency, and freedom from hazards, always with the greatest consistent economy. There is a tendency to consider distribution problems as being rather stereotyped, but it is believed that this view is fallacious and that generalized studies are needed to establish correlation between load densities and the economics of various distribution schemes.

Rate structures are related closely to the distribution problems, and elements which were not fully anticipated nor provided for originally have presented serious problems such as the wattless component of the load. The necessity of providing capacity to handle demand and maintain voltage within the limits prescribed will be an increasing source of expense and annoyance until the rates fully recognize the costs involved. Practically all distribution systems require modernization, for there are few systems which have been built with a constant program for culling out the obsolete, the worn out, or the inefficient portions. Changes in load such as a multitude of small motors running under partial load and welding have increased the amount of lagging current which has led to full load or overload distribution conditions in many instances.

In addition to the industrial load problems, residential and commercial services have undergone changes. A great number of small motors for air conditioning and heating units and fluorescent lighting have done much to increase the load. It would appear that the 120-volt secondary utilization voltage is rather antiquated. In view of the existing copper shortage, consumer wiring costs, and distribution facilities, 240 volts for the lowest single-phase utilization voltage offers many benefits. Such a change would require that consumers convert their facilities, which in view of their own increasing loads might prove economical. Instead of the now common practice of dual secondary circuits, it is possible that an initial single-phase secondary system, to be expanded to a 3-phase system whenever 3-phase loads were added or whenever the single-phase load density increased to such an extent as to warrant reinforcement, might prove advisable. A suggestion for combination of these two possibilities is either a 240-volt delta secondary or a 240/416-volt Y secondary system. In addition it is advised that interconnected secondaries would permit greater diversity and the over-all requirement for transformer capacity would be reduced.

For industrial areas it is interesting to note that aerial cable may prove to be most valuable in increasing capacity over open wire construction because of its capacitive impedance characteristic. Primary distribution voltages have approached the limit which can be worked safely when energized, and changes would be costly and complicated. Present levels can be utilized to good advantage for even greater load densities if the primary distribution schemes are modified in accordance with their limitations. One means of accomplishing this is by use of looped primaries. Some transmission voltages also may be increased advantageously to levels between 22,000 and 33,000 volts, where loads are heavy and transformers relatively few in number.

With regard to voltage regulation, some of the problems are: standard tolerance or allowable regulation, fixed or elastic tolerances, and allowance for appreciable variation over nominal as well as under nominal voltage. It might be more economical for the customer to pay more for equipment capable of operating satisfactorily over a wider voltage range, to pay more for energy losses, and not have to pay so much more for the uniform voltage delivery required with less versatile and cheaper equipment. Another important consideration is the matter of voltage schedules with short peak load requirements being less deserving than average load requirements.

It is believed that use of capacitors will be of benefit to power secondaries. The packaged or unit type of substation also will be valuable in co-ordination with other plans of modernization. Modification of street lighting schemes by use of carrier current instead of time clocks and overhead switch wires is a problem in a specialized form of distribution.

The use of aerial cable in overhead construction, greater life expectancy of poles, changing of availability and price of suitable metal conductors, and use of underground construction all were mentioned in the symposium. In conclusion it was noted that safety scarcely had been mentioned, because of a belief that in any part of an electric system safety always shall be considered.

Discussion followed the presentation by Jung and Blankenburg, and W. J. Walsh (A '38) distribution engineer, electric transmission and distribution department, San Diego Gas and Electric Company, Calif., pointed out that the problem of the most economical secondary system used in light of present and foreseeable future residential loads and service requirements has arisen from time to time, usually during a period of unusual expansion such as at present. However, records indicate that appreciable time is required to establish any considerable saturation of any new type of residential load. A recent paper, "Modern Secondary Adequate for Coming Home Loads" by D. K. Blake (M '39) electrical engineer, General Electric Company, Schenectady, N. Y., was cited which presented data to demonstrate that the existing 120/240-volt single-phase secondary system is the most economical, and is fully capable of handling any foreseeable loads, including heat pumps and house heating. However, Mr. Blake's analysis was mentioned as being based, of necessity, on certain simplifying assumptions, and did not take into consideration facilities and equipment required beyond the metering point. An analysis of the over-all system as well as of secondary design, which would include utilization equipment and facilities beyond the metering point, would be highly desirable. It also was mentioned that static capacitors as suggested in the paper had been used on the street lighting load of the San Diego Gas and Electric Company with good results since 1941. Present standard practice with this company calls for installation of a 15-kva capacitor with each pole-type constant-current street-lighting transformer of $7^{1}/_{2}$ kva or larger.

Further discussion by F. L. Goss (M '45) and A. L. Williams (A '47) senior electrical engineers, Department of Water and Power, City of Los Angeles, Calif., pointed out that in approaching the problem of the economics of distribution changes it always must be kept in mind that no other part of the utility system is so much the product of local factors. The geographic character and extent of the system; maximum and minimum load densities and their contiguous or noncontiguous nature; relative proportion of residential, commercial, and industrial loads and their location on the system; load growth rates and estimated future load densities; and other similar factors all have a profound effect. Modifications of distribution systems must take into account the effect on the existing systems, amount of waste, effect on service, effect on operating and maintenance costs, extent to which it is nonstandard compared to existing materials in use, and involvement in other problems.

Mention was made that most utilities have a mass of line and equipment failure records which, when properly correlated and digested, might form an excellent approach to the distribution problem. Such a study would provide a basis for determining the relative amount of money justified in spending in the various portions of the distribution systems to provide continuity of service. The discussers said that 33,000-volt primary distribution has been established in the Los Angeles system satisfactorily. It also was mentioned that carrier current had been used in connection with street lighting without too much success because of the difficulty in securing a dependable relay. However, it is felt that carrier current for switching certain loads is fundamentally sound and that it may offer a method for control of other loads which can be arranged conveniently for off-peak operations.

The discussion brought out that there is considerable room for a closer co-operation between the design sections of the manufacturers of utilization equipment and the distribution design engineers who have the problem of serving this equipment. Also pointed out was the fact that perhaps the first step in distribution modernization is to impress upon management that distribution is not stereotyped, and that while a multitude of smaller projects are not as dramatic or spectacular as a generation or transmission project, they constitute a large portion of system investment, involve a major portion of system losses, and certainly merit an adequate staff properly equipped to carry on continuous research in distribution problems.

"Excitation Problems in Hydroelectric Generators Supplying Long Transmission Lines" by C. L. Killgore (A '37) electrical engineer, United States Bureau of Reclamation, Denver, Colo., explained that a satisfactory excitation system must be capable of maintaining voltages within specified limits when a hydroelectric generator is operating underexcited with a lightly loaded transmission line or overexcited with a fully loaded transmission line. In addition to protecting against severe overvoltages, a satisfactory excitation system should be capable of increasing the stability limits of the transmission system and of preventing pull-out from insufficient excitation. From the apparent superior performance and relative simplicity of the recently developed excitation system consisting of a stabilized self-excited main exciter and a static voltage regulator with a rotating amplifier, it appears that this type of excitation may become standard for hydroelectric generators supplying long transmission lines. The term "stabilized" describes the design of an exciter which intentionally controls saturation to give a positive crossing of the saturation curve with any field resistance line needed for the full range of operation. The rotating amplifier replaces a pilot exciter and is driven by an a-c motor from the station service power system. Very little control power is required from the static voltage regulator to adjust the field of the rotating amplifier.

The method of calculating and plotting tension–length curves for suspended conductors was explained in "Broken Conductor Effect of Sags in Suspension Spans" by Alfio Bissiri and Maurice Landau of the Department of Water and Power, City of Los Angeles, Calif. The method of calculation was devised in order that every crossing of other transmission lines, railroads, communication lines, and highways would have proper clearance maintained. The problem is to determine the change incurring in a suspension span or series of spans from one condition of static equilibrium to another, which is caused by a variation in one or more of the factors that determine the equilibrium of the span involved.

"Tests and Developments in Connection With 'Hot'-Line Insulator Washing" by T. Leslie Hill (M '43) assistant engineer, bureau of tests and inspection, Pacific

Gas and Electric Company, Emeryville, Calif., pointed out that contaminated and dirty insulators are a source of considerable maintenance expense, trouble, and annoyance to electric power utilities. Large expenditures have been made in the past for cleaning insulators by wiping them by hand. Experiments were conducted by the Pacific Gas and Electric Company in washing energized insulators with a high-pressure stream of water. Playing a stream of water on an energized power line or insulators was practically unheard of until a few years ago, because of safety education. Tests were conducted to determine leakage current through a water stream and it was observed that it is very unlikely that workmen will get nearer than the minimum safe distance determined. If a workman inadvertently should turn a stream of water on an energized line that was too close, the current obtained would be above the "let-go" value of 10 to 15 milliamperes and he automatically would break the circuit continuity by muscular reaction of moving the nozzle.

Several types of nozzles were tested and it was found that a set of well-built and highly-polished nozzles of various sizes were essential for successful insulator washing. Design of the nozzle must be such that the stream remains solid for a sufficient distance. The reduced expense of cleaning insulators by washing allows more frequent cleaning and to a great extent eliminates pole-top fires.

Two Sessions on Communications and Electronics

D. I. Cone (M'42) transmission and protection engineer, Pacific Telephone and Telegraph Company, San Francisco, Calif., presided over both sessions on communications. The first session was in the morning on Thursday, August 28, and the second was in the afternoon on the same day.

Design faults which frequently have been overlooked by manufacturers were pointed out in "Design Problems Encountered in Capacitor Stored Energy Spot Welding Equipment," a conference paper by J. C. Rapp, Lockheed Aircraft Corporation, Burbank, Calif. The three basic units of spot welders are: the welding machine, the sequencing control, and the welding power control. The units are treated individually because they frequently are purchased separately, which fact is responsible for one of the most apparent weaknesses in them. This weakness is the lack of interlocking between the welding machine and its sequence control and the energy storage and discharge control equipment.

Consistency of performance and freedom from breakdown are prime considerations in the user's view of the required characteristics of the subject machine. Most important of the necessary features are

1. Double pressure operation with provision for initiating the weld by means of a device operated by the electrode force.

2. Forging pressure controlled by a timing unit accurate within plus or minus five milliseconds.

3. A sequence control which is interlocked with welding power controls to prevent initiation of the weld until the capacitors are charged properly.

4. A control circuit for selecting and charging the capacitors which will prevent absolutely interconnection of charged and discharged capacitors with each other or with the charging bus.

5. A rectifier which will hold the capacitor voltage within 0.5 per cent of any preset voltage between 1,200 and 3,000 volts on capacitors as small as 120 microfarads.

6. Rectifier blocking which will take effect at least one-half cycle of line frequency before weld initiation.

7. An initiating circuit for the shunt or reverse series tube which will prevent ignition of the tubes until the capacitor voltage is correct.

In discussing "Design and Application of Supersonic Flaw Detectors," a technical program paper, Donald C. Erdman, Tripett and Barton, Inc., Burbank, Calif., gave general parameters for circuits that make up echo-type supersonic flaw detectors used in the location of defects in large metal forgings. High-frequency sound waves traveling the length of a metal bar behave quite similarly to a transient electric signal in a long transmission line, and abrupt changes in the distributed capacitance or inductance cause a portion of the transient signal to reflect back toward the generator. At high frequencies echoes can be detected from large grain boundaries. The detector unit utilizes a small quartz crystal used as a transducer to convert electric energy into pressure waves and vice versa; thus one crystal unit acts both as a loud-speaker and a microphone. The amplifier associated with the equipment must have at least 100-decibel gain in order to bring the echo signals to a level that can be handled by most syncroscopes. A syncroscope with a delayed sweep, which is accurate and free of jitter, is used for indicating.

"Random Phenomena in Signal-to-Noise Ratio," a conference paper by Simon Ramo (M'43) and R. H. Delano, both of the Hughes Aircraft Company, Los Angeles, Calif., emphasized the need for presenting to operating and design engineers factors involved in obtaining optimum signal-to-noise ratio in vacuum-tube amplifiers with more detail of design information than is available in handbooks, and in a form more suitable for general practioners than the highly specialized reports on research that are available. Mr. Delano reviewed the fundamental limitations presented by thermal noise at low frequencies, the effect of shot noise, space charge, and the increasing importance of transit time as frequency is raised. Consideration of the relationship between operating temperatures, dimensions, frequencies, and performance objectives determines the choice of apparatus for new designs of best utilization of available equipment.

"Design of Electronically Regulated D-C Power Supplies," a conference paper by D. C. Kalbfell, Kalbfell Laboratories, San Diego, Calif., presented design equations of an electronic voltage regulating network considering separately the conditions of fluctuating load and of varying supply voltage leading to systems engineered to give the best performance for specific application, and to systems for general laboratory use giving adequate performance over the widest range of output voltages and currents. Degenerative vacuum-tube amplifiers may be used to maintain constant direct voltage at the output of a rectifier system regardless of variations in load or supply voltage. The degree of elaboration of design and corresponding requirements for equipment depend upon the range of operation and precision of regulation specified. Such regulated power supply systems are used commonly in vacuum-tube voltmeters, calibrated amplifiers, and other electronic instruments.

Some rarely suspected sources of distortion were presented in "Some Observations on the Design and Maintenance of Low Distortion Audio Systems" by J. R. McGaughey, Navy Electronics Laboratory, San Diego, Calif. The process of minimizing distortion in two amplifiers (using the intermodulation method for the indication of nonlinear distortion) was reported in detail. A plea was made for the inclusion of distortion characteristics with all published audio equipment data. Some of the observations were that tolerance in amplifier components is considerably less than has been believed widely; that in the case of triodes, optimum grid bias voltage is critical and is best found experimentally; that the phrase "ten per cent unbalance in push-pull stages is not serious" is not true, unless one is willing to tolerate fairly large amounts of distortion, and that benefit of push-pull operation depends upon symmetry which must be kept as good as possible; mid-branch impedances such as common cathode or screen resistors must be by-passed otherwise the amplifier acts as a modulator; and frequent checks must be made on equipment if it is to be maintained at peak performance. In elaborate permanent systems such as broadcast studios. recording laboratories, or research installations, adequate performance analyzing equipment might well be built into the racks.

"Intermodulation Testing," a conference paper by R. M. Lee and H. L. Smith (Student Members) University of Utah, Salt Lake City, was written as an undergraduate thesis presenting a review of the subject. There are advantages in applying two tones to an amplifier instead of one to produce intermodulation frequencies which have no harmonic relationship with the frequencies that produce them, and whose relative amplitudes provide a good indication of amplifier quality. Some of the factors affecting the problem of good audio reproduction and the relative importance of the method with results obtained from applying tests to several different amplifiers were presented.

Aircraft Industry Stressed in Two Industrial Sessions

W. C. Smith (F'40) General Electric Company, San Francisco, Calif., presided at both the morning and afternoon industrial sessions on Thursday, August 28.

"Ground Power Supply for Modern Aircraft," a technical program paper by T. B. Owen (A '43), J. A. Murray (A '45) both of Douglas Aircraft Company, Inc., Santa Monica, Calif., and Allen B. Rosenstein (A '41) University of California, Berkeley, presented the problem of providing a ground power supply for an airplane with a maximum load of 200 amperes. The very large increase in electrical loads on aircraft now in production, and the definite trend for still larger loads, has made it necessary to review present ground power facilities. Ground power is the term applied to a source of electric power external to the airplane necessary to ground operation. Two basic types of ground power supply are rotary and static equipment for supplying 28 volts of direct current. Ground power supplies can be made either stationary or mobile, the latter being more popular for present day operation. The heaviest load imposed on the ground power supplies are those for aircraft engine starting and propellor pitch testing. Under these final ground conditions, power supply must be capable of supplying a minimum of 600 amperes continuously, and possibly up to 1,800 amperes.

In the discussion the importance from the passenger standpoint was emphasized providing full lighting and air conditioning on the ground in order to provide a favorable impression. Experience seems to be proving that rectifiers are more reliable than motor generator sets, and that with suitable electronic control the voltage regulation is also better with rectifiers.

"Electric Equipment Required in a Modern 6-Component Wind-Tunnel Model Suspension System," a technical program paper by H. Orville Cox (A '35) Bechtel Brothers McCone Company, Pomona, Calif., pointed out that to retain the value of the wind tunnel's operating possibilities, it is a prime consideration that the design and construction of the model handling and force measurement equipment be such that a minimum of time is lost in rigging, making adjustments, and instrumenting the models used in the test section. The metrical or force measuring elements, however, always the fundamental parts of any balance system, are incorporated in the "model suspension system," a term given to the model handling facilities in variable-density wind tunnels. The six components that the aerodynamicists are interested in when taking force measurement on a tunnel model in its various attitudes of angle of attack and yaw are: lift, drag, crosswind, pitching moment, yawing moment, and rolling moment. The modern suspension system is capable of moving the model in the tunnel in both angle of pitch and yaw and can do both simultaneously. An image system needed to give double tare forces in order that the main support tares can be determined is included. The system also is powered by automatic following drive. Major supporting members are assembled on structures which allow models to be placed in the tunnel test section or rolled out of it in a matter of a few minutes.

The instrumentation equipment has reached the point where sensitivity of as low as 50 pounds on lift and 10 pounds on drag is reached. All equipment must be extremely reliable because of the difficulty of access.

"A New Grinding Circuit Speed Regulator," a technical program paper by J. N. Jones (A '45) district engineer, Westinghouse Electric Corporation, Los Angeles, Calif., described the application of a feed regulator for a ball mill, although similar regulators can be adapted to control other crushing or grinding processes, especially where there exists a long time delay between the corrective step and the resultant change in the medium being controlled. In the process described four variables are involved: crushing, grinding, copper recovery by flotation, and dewatering and filtering of final concentrates. Timing devices, relays, and rheostats act to actuate conveyors, valves, and grinding motors in continuous operation.

The efficiency of electric equipment employed in grinding operations is highly important because the very large tonnages worked on cause small individual losses to add up to large amounts. Special consideration must be given to the matter of time lag because, in some instances, ten minutes elapse before a change is evidenced. Therefore, a scheme of instrumental timing is employed to avoid serious hunting.

L. J. Rich, Lockheed Aircraft Corporation, Burbank, Calif., described a system of monorail cranes installed in a Lockheed plant in a conference paper, "Speed Control for Monorail Cranes." The crane system developed for control of 3-phase slip ring induction motors with external resistance connected in the rotor circuit complied with safety regulations in having at least six conductors between cab and bridge. Appropriate contactors made it possible for the crane motors to run at three different speeds forward and three reverse. Time-delay relays were included in the circuit to control acceleration of the bridge, and lock-out relays in each cab prevented conflict in the event that two cabs were present on the same bridge.

Very accurate control of the overhead cranes is essential in an airplane assembly plant to allow for placing of parts (often large assemblies) in exact positions for lining up bolt holes.

Several examples of the various types of vibration problems facing the engineer and the operator of rotating machinery were presented in "Field Problems in Balancing Rotating Electric Machinery," a conference paper by R. B. Barton, General Electric Company, Los Angeles, Calif. Vibration problems stem from other than dissymmetry of rotating parts such as mechanical disturbances, thermal disturbances, instability, and straight forward balance. To solve the problem, rotating speed, speed and accuracy with which data may be obtained. known interference from other sources, equipment available, and familiarity of the operator with his equipment must be considered. Solution may be in two parts which sometimes complicates matters.

The extreme importance of definitely determining the nature of vibration was brought out by several discussers, and instances were cited, such as bipolar vibration, to prove that many suspected unbalanced are troubles not the result of unbalance. The final tolerances allowed are largely a matter of judgment, and must be gauged to result in satisfactory life of the apparatus.

"General Analysis of Speed Regulators Under Impact Loads," a technical program paper by G. D. McCann (M '44) California Institute of Technology, Pasadena, W. O. Osbon (M '41) research engineer and H. S. Kirschbaum (A '43) industry engineering department, both of Westinghouse Electric Corporation, East Pittsburgh, Pa., presented the results of a study that has been made on the transient speed response of basic forms of speed regulating systems to suddenly applied square-wave load torques. Solutions were obtained on a transient analyzer and electrical analogies for the systems were developed. The solutions are applicable to d-c motor drives with either variable armature voltage or motor field current control and two inherent time delays, one of which must be in the motor armature circuit. Stabilization is effected by means of an anticipatory resistive-capacitive circuit immediately following the error signal and a resistive-capacitive feed-back circuit just after the first inherent time delay. In the design and application of modern precision rolling mill speed control equipment, it has been found highly desirable to make complete transient response calculations under the transient conditions of billets entering the rolls. The solution presented can be used not only for the design of systems to operate at a specific speed or over a range of speed by armature voltage control, but also for most cases where systems operates over a range of speed by motor field current variation.

A close response is necessary to eliminate stretching or buckling of the material being rolled. Although flywheels assist, extreme precision is obtained only through the provisions of electronic control.

District Awards Announced for Prize Papers

District prizes for AIEE papers have been announced by six Districts. Each District prize consists of an appropriately engraved certificate and check for $25, divided in instances of coauthors.

DISTRICT 1

Prize for Branch paper was awarded to Ralph O. Williams for his paper, "Electronic Fractional Horsepower Torque Measuring Indicators," presented at the North Eastern District meeting, Worcester, Mass., April 24–26, 1947.

DISTRICT 3

Prize for Branch paper was awarded to Milton Frank Pravda for his paper, "Graphical Method of Determining the A-C Resistance in Single-Layer Coil," presented at the District student conference, May 2, 1947, in New York, N. Y.

DISTRICT 5

Prize for Branch paper was awarded to Howard M. McConnell for his paper, "Progressions Applied to Engineering Problems," presented at the Great Lakes District student conference, South Bend, Ind., May 2, 1947.

Prize for graduate student paper was awarded to Richard B. Edgar (A '45) for his paper, "Design of Unilateral Mutual Impedances," presented at the Great Lakes District student conference, South Bend, Ind., May 2, 1947.

DISTRICT 6

Prize for Branch paper was awarded to John C. Wheatley and Robert A. Mathias for their paper, "Voltage Regulator for Electronic Exciters," presented at the student conference, Laramie, Wyo., April 25–26, 1947.

Prize for graduate student paper was awarded to Ralph D. Goodrich (A '46) for his paper, "Five-Channel Electronic Switch," presented at the student conference, Laramie, Wyo., April 25–26, 1947.

DISTRICT 7

Prize for Branch paper was awarded to James R. McDade for his paper, "The Phantastron Single-Tube Control Circuit," presented at the student conference, University of New Mexico, Albuquerque, N. Mex., May 6, 1947.

Prize for graduate student paper was awarded to Henry E. Webking for his paper, "A Family of Vacuum-Tube Characteristic Curves on the Cathode-Ray Oscilloscope," presented at a meeting of the Oklahoma Agricultural and Mechanical College Branch, Stillwater, Okla., March 31, 1947.

DISTRICT 10

Prize for best paper was awarded to James M. Vanderleck (A '45) for his paper, "The A-C Potentiometer," presented at a meeting of the Toronto (Ontario, Canada) Section, January 25, 1946.

Bibliography Available on High-Frequency Heating

A bibliography on high-frequency dielectric heating, compiled by Ralph A. Rusca of the Southern Regional Research Laboratory, New Orleans, La., and recommended for publication by the AIEE committee on electronics, has been completed and now is available from the Institute in pamphlet form. This annotated bibliography is one of the most comprehensive published on the subject thus far, and should prove a valuable aid to the research worker or engineer interested in evaluating the dielectric heating process, or applying it to his specific problem. It covers publications from 1925 to July 31, 1946, and includes 231 domestic references, 62 foreign references, 56 domestic patents, and 44 foreign patents (British, French, and German).

Copies of the "Bibliography on High-Frequency Heating" may be obtained from the AIEE Order Department, 33 West 39th Street, New York 18, N. Y. The price to AIEE members is 35 cents, to nonmembers, 75 cents.

1946 Survey of Engineers Profession Available from AIEE

At its last meeting the board of directors voted a sufficient increase in the appropriation of the committee on the economic status of the engineer to permit the purchase of 2,000 copies of the 1946 survey of the engineering profession entitled, "The Engineering Profession in Transition." This report has been reviewed by William N. Carey, chairman of the surveying committee, in *ELECTRICAL ENGINEERING* (*EE, Sept '47, pp 869–72*).

The report is to be sold for $1 with a 50 per cent discount to AIEE members.

PERSONAL • • • • •

Harold Edward Strang (A '28, M '39, F '45) assistant to the vice-president, apparatus design engineering department, General Electric Company, Schenectady, N. Y., has been appointed 1947–48 chairman of the Charles LeGeyt Fortescue Fellowship committee. Mr. Strang, who was born in Mechanicville, N. Y., in 1901, received the degree of electrical engineer from Rensselaer Polytechnic Institute in 1922 and thereupon was employed in the testing department of the General Electric Company, Schenectady, N. Y. He was transferred to the switchboard engineering department in 1924 and to Philadelphia, Pa., to take charge of design of large oil circuit breakers in 1929. In 1931 he was given additional charge of their manufacture. He was appointed engineer of the Philadelphia works in 1940 and assistant to the vice-president in 1944. Mr. Strang served as chairman of the Philadelphia Section of the AIEE in 1943–44 and was chairman of the AIEE committee on protective devices for 1944–45.

Robin Beach (A '15, M '21, F '35) consulting engineer, Brooklyn, N. Y., has been appointed chairman of the AIEE committee on safety for 1947–48. He was born at Robin's Island, Long Island, N. Y., August 30, 1889, and received the degrees of bachelor of science in electrical engineering (1913) and electrical engineer (1922) from the University of New Hampshire, and the degree of master of science in physics (1922) from New York University. From 1913 to 1918 he served on the faculties of the University of Illinois, Urbana; Texas Agricultural and Mechanical College, College Station; and Norwich (Vt.) University. In 1918 he was appointed to the electrical engineering faculty

Modern Buildings in Mexico City

Banco De Mexico and other modern buildings (left), and the Palace of Fine Arts (right) in the city of Mexico, Mexico, site of the 1948 AIEE summer general meeting

W. C. Smith

Robin Beach

G. W. Scott, Jr.

of the Polytechnic Institute of Brooklyn as associate professor. He became professor in 1927 and in 1930 was appointed head of the department of electrical engineering. He resigned in 1945 to organize the consulting engineering firm of Robin Beach Engineers Associates. Professor Beach also was educational director of the Brooklyn Edison Company from 1922 to 1933. He has served on the AIEE committees on production and application of light (chairman 1937–38) and education (chairman 1942–43). He has been AIEE representative on the International Commission on Illumination since 1937. He is a member of the American Society for Engineering Education, Eta Kappa Nu, and Tau Beta Pi.

George William Scott, Jr. (M '45) assistant chief physicist, Armstrong Cork Company, Lancaster, Pa., has been appointed 1947–48 chairman of the AIEE committee on electric heating. Doctor Scott was born in 1912 in Auburn, N. Y., and holds the degree of bachelor of arts (1934) from Wesleyan University and the degrees of master of arts (1935) and doctor of philosophy (1938) from Cornell University. From 1938 to 1940 he had a postdoctorate fellowship in applied electronics at Massachusetts Institute of Technology, Cambridge, and in 1940 became research associate at the institute. He joined the Armstrong Company in 1941. Doctor Scott was recipient of the AIEE 1945 national prize for initial paper and is a member of the American Physical Society, the American Welding Society, and Sigma Xi.

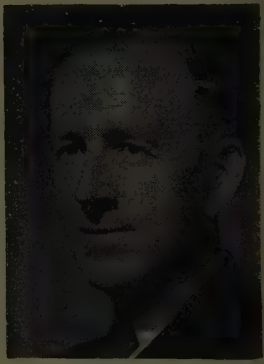
Reginald Lamont Jones (A '11, M '17, F '31) vice-president, Bell Telephone Laboratories, Inc., New York, N. Y., has been appointed 1947–48 chairman of the AIEE Standards committee. Doctor Jones was born in New York, February 28, 1886, and received the degrees of bachelor of science in 1909, master of science in 1910, and doctor of science in 1911, from the Massachusetts Institute of Technology. He entered the Bell System as a member of the research staff of the Western Electric Company, New York, N. Y., in 1913. In 1914 he was placed in charge of the transmission research department. He took charge of the inspection engineering department in 1923, and, when Bell Laboratories was formed in 1925, he continued in that position with the laboratories. He was made head of the outside plant development department in 1927 and director of apparatus development in 1928. Doctor Jones was appointed to represent the AIEE on the Engineers Defense Board in 1941 and also had served on the AIEE committee on constitution and bylaws, of which he was chairman for 1946–47. His other society affiliations include the American Physical Society, the Acoustical Society of America, the American Association for the Advancement of Science, and the Academy of Political Science.

Louis Warrington Chubb (A '09, F '21) director of research, research laboratories, Westinghouse Electric Corporation, East Pittsburgh, Pa., has been appointed chairman of the AIEE committee on nucleonics for 1947–48. Doctor Chubb was born October 26, 1882, in Fort Yates, N. Dak., and was graduated from Ohio State University in 1905 with the degree of mechanical engineer in electrical engineering. As an engineering apprentice with the Westinghouse Corporation from 1906 to 1910, he worked on the development and testing of sheet steel and did research on transformers. He was placed in charge of the electrotechnical and magnetic research section in 1910 and the research work of the material and process engineering department in 1919. When the radio engineering department was organized in 1920, Doctor Chubb was made manager. He left East Pittsburgh in 1930 when the radio activities of the Westinghouse Corporation, the General Electric Company, and the Radio Corporation of America were consolidated at Camden, N. J., to become assistant to the vice-president of RCA. Later that year he returned to East Pittsburgh as director of research. He has been granted about 200 patents for electrical, mechanical, electrochemical, and instrumental development. He has received the degrees of doctor of science from Allegheny College and from the University of Pittsburgh. In 1934 he was awarded the Lamme Medal of Ohio State University and in 1946 the John Fritz Medal. He is a member of the American Association for the Advancement of Science, the American Physical Society, the Franklin Institute, the Institute of Radio Engineers, the Illuminating Engineering Society, and the National Electrical Manufacturers Association.

Walter Charles Smith (A '07, M '26, F '40) retired district engineer, General Electric Company, San Francisco, Calif., has been appointed 1947–48 chairman of the AIEE committee on constitution and bylaws. Mr. Smith, who was born in Clarkston, Mich., January 9, 1882, was graduated from the University of Michigan in 1905. That same year he entered the testing department of the General Electric Company, Schenectady, N. Y. In 1907 he was made assistant designer of reactors and railway compensators and in 1908 was transferred to Pittsfield, Mass., as chief designer. While at Pittsfield he rose to the position of assistant engineer of the transformer engineering department. From 1918 to 1920 he did special investigation work for this department with his headquarters at Denver, Colo., and in 1920 he was made transformer specialist at the San Francisco office. He became assistant engineer in 1931 and chief engineer in 1932. He was appointed engineer of the company's Pacific district in 1940. Mr.

H. E. Strang

L. W. Chubb



R. L. Jones

C. G. Suits

J. D. Leitch

L. H. Hill

Smith was chairman of the AIEE Pittsfield Section for 1912–13 and of the San Francisco Section for 1933–34. He was chairman of the program committee of the AIEE Pacific convention in San Francisco in 1939 and AIEE vice-president for 1941–43. He currently is serving on the AIEE board of directors. He is past chairman of the San Francisco Engineering Council and a member of the San Francisco Engineers Club. In 1925 Mr. Smith received the Coffin Award from the General Electric Company for transformer design.

Leland H. Hill (A'22, M'29, F'38) publisher, *Electrical World*, New York, N. Y., has been appointed 1947–48 chairman of the AIEE committee on management. Mr. Hill was born March 8, 1899, in Toms River, N. J., and was graduated from Cornell University, Ithaca, N. Y., with a degree in electrical engineering. He was instructor at the university from 1920 to 1922 and in the latter year became design engineer, transformer engineering department, Westinghouse Electric Corporation, East Pittsburgh, Pa. In 1928 he was made manager of the transformer division of the American Brown Boveri Electric Corporation, Camden, N. J. When the Brown Boveri Company was absorbed by the Allis-Chalmers Company in 1931, Mr. Hill was made assistant manager of the electrical department and then vice-president in charge of industrial relations. He became publisher of *Electrical World* in 1945. Mr. Hill holds approximately 40 patents on electric machinery and is the author of a text on transformers. Throughout World War II, Mr. Hill was active on the World Labor Board. He is co-author of "Management at the Bargaining Table."

John Davie Leitch (A'38, M'42) chief engineer, Electric Controller and Manufacturing Company, Cleveland, Ohio, has been appointed 1947–48 chairman of the AIEE committee on industrial control. Mr. Leitch was born in Glasgow, Scotland, May 20, 1900, and holds the degree of bachelor of science in electrical engineering from the University of Glasgow (1925) and the degrees of master of arts (1933) and doctor of philosophy (1939) from the University of Toronto. From 1927 to 1930 he was lecturer in physics at the University of Toronto, Ontario, Canada. He was consultant physicist on radium and X rays for the Ontario Department of Health, Toronto, from 1932 to 1937 in connection with its cancer program. Having spent the years 1930 to 1932 as Toronto sales representative of the Electric Controller Company, he returned to the employ of the company in 1937 as development engineer and was made chief engineer in 1943.

Chauncey Guy Suits (M'41, F'47) vice-president and director of research laboratory, General Electric Company, Schenectady, N. Y., has been appointed 1947–48 chairman of the AIEE committee on research. Doctor Suits was born March 12, 1905, in Oshkosh, Wis., and holds the degrees of master of arts (1927) from the University of Wisconsin and doctor of natural science (1929) from the Technische Hochschule, Zurich, Switzerland. He entered the research laboratories of the General Electric Company in 1930 and was made assistant director in 1940. He became vice-president and director of the laboratories in 1945. His many inventions include measurements of high temperature arcs, improvements in railway block signals, radio circuits, beacons, submarine signals, theater light dimmers, and photoelectric relays. He is the author of numerous technical papers and is a member of the National Academy of Sciences, the American Physical Society, Phi Beta Kappa, and Sigma Xi. He was the recipient of the 1937 Eta Kappa Nu award.

Harold Winograd (A'26, M'39, F'46) engineer in charge of rectifier design, electrical department, Allis-Chalmers Manufacturing Company, Milwaukee, Wis., has been appointed 1947–48 chairman of the AIEE committee on electronic power converters. Born September 12, 1900, in Russia, Mr. Winograd was graduated from Cornell University in 1924 with the degree of electrical engineer. In 1925, after a year and a half in the test department of the United Electric Light and Power Company, New York, N. Y., he joined the American Brown Boveri Electric Corporation, Camden, N. J., as rectifier engineer. When that company was purchased by the Allis-Chalmers Company in 1931, he was given supervision of the design of rectifier equipment. Mr. Winograd received honorable mention in the 1944 AIEE national prize award in the field of engineering practice. He is co-author of the book "Mercury Arc Power Rectifiers," and author of several technical papers. He holds a number of patents and has served for several years on the AIEE committee on electronics.

Benson McHardy Jones (A'20, M'24 F'42) planning engineer, planning and development department, Duquesne Light Company, Pittsburgh, Pa., has been appointed chairman of the AIEE publication committee for 1947–48. Mr. Jones, who was born in Newberry, S. C., November 23, 1891, received the degrees of bachelor of science (1914) and electrical engineer (1934) from Clemson Agricultural and Mechanical College. From 1914 to 1923 he was associated with the Westinghouse Electric Corporation, East Pittsburgh, Pa., which he joined as test engineer in 1914. He became steel mill engineer in 1918 and construction engineer in 1921. His association with the Duquesne Light Company commenced in 1923, and he has been switchboard and control engineer, relay

B. M. Jones

Harold Winograd

C. F. Wagner

J. E. Hobson

H. M. Turner

L. A. Umansky

engineer, and general engineer. Since 1931 he has been a member of the system planning and development department. Mr. Jones has been an active member of the Pittsburgh Section. He also is a member of the Engineering Society of Western Pennsylvania, which he has served as director, of the Edison Electric Institute, and of the Pennsylvania Electric Association.

Charles Frederick Wagner (A'20, M'27, F'40) manager, central station engineering department, Westinghouse Electric Corporation, Pittsburgh, Pa., has been appointed 1947–48 chairman of the AIEE committee on transmission and distribution. Born in Pittsburgh, Pa., March 20, 1895, Mr. Wagner was graduated from Carnegie Institute of Technology in 1917 with the bachelor of science degree. His entire professional career has been with the Westinghouse Corporation which he joined in 1918 after a year of graduate study at the University of Chicago. During this time his work has included research and development of mercury-arc rectifiers and inverter systems; the study of transmission system stability and short-circuit transients; and the analysis of machine performance and high voltage lightning phenomena. In 1938 he was appointed consulting transmission engineer and in 1941 manager of the central station engineering department. Mr. Wagner has served on the planning and co-ordination committee and the transformer subcommittee of electric machinery committee. He was chairman of the AIEE publications committee for 1945–46. In 1938 he received best paper prize in engineering practice and in 1943 in theory and research.

Jesse Edward Hobson (A'36, M'41) director, Armour Research Foundation, Chicago, Ill., has been appointed 1947–48 chairman of the AIEE committee on registration of engineers. He was born in Marshall, Ind., May 2, 1911, and received the degrees of bachelor of science (1933) in electrical engineering from Purdue University and of doctor of philosophy (1935) from the California Institute of Technology. He taught at Earlham College, Richmond, Ind., and Armour Institute of Technology before joining the Westinghouse Electric Corporation in 1937. He became central station engineer for the company in 1938. In 1941 he was appointed director of the electrical engineering department at Illinois Institute of Technology, Chicago, and in 1944 director of the Armour Research Foundation. Professor Hobson was named by Eta Kappa Nu as the outstanding young electrical engineer for 1940. He is a member of Sigma Xi and Tau Beta Pi and the author of several technical papers.

Leonid A. Umansky (A'16, M'27, F'45) assistant manager, industrial engineering division, General Electric Company, Schenectady, N. Y., has been appointed chairman of the AIEE committee on general industry applications for 1947–48. Mr. Umansky was born in Russia, July 23, 1890, and was graduated from the Polytechnic Institute of Petrograd. After serving as a member of the Imperial Russian Artillery Commission, he entered the testing department of the General Electric Company in 1919 and was transferred to the industrial engineering department as steel mill application engineer in 1920. He was placed in charge of the steel mill section in 1936 and was appointed assistant manager of the industry engineering division in 1940. He has written technical articles and is a member of the Association of Iron and Steel Engineers.

Hubert Michael Turner (M'20, F'44) associate professor of electrical engineering, Yale University, New Haven, Conn., has been appointed 1947–48 chairman of the AIEE committee on award of Institute prizes and of the technical program committee. Born in Hillsboro, Ill., July 20, 1882, Professor Turner received the degrees of bachelor of science (1910) and master of science (1915) from the University of Illinois, and was instructor at that university from 1910 to 1912. He joined the faculty of the University of Michigan as instructor in electrical engineering in 1912 and in 1918 became assistant professor at Yale University. He was appointed associate professor in 1926. Professor Turner has been chairman of the Institute committee on communication and has served on the committee on instruments and measurements.

He holds a number of patents and is the author of numerous technical papers. He also is a member of the Institute of Radio Engineers, International Scientific Union, The American Association for the Advancement of Science, Franklin Institute, American Society for Engineering Education, Eta Kappa Nu, and Sigma Xi.

Harry Barker (A'05, M'13) consulting engineer, Barker and Wheeler, engineers, New York, N. Y., has been appointed chairman of the AIEE committee on code of principles of professional conduct for 1947–48. Born July 19, 1881, in Rutland, Vt., Mr. Barker was graduated from the University of Vermont in 1904 with the degree of bachelor of science in electrical engineering. After a year as instructor at the University of Vermont, Burlington, Mr. Barker engaged in design work until 1907. He was editor of *Engineering News* and *Engineering News-Record* from 1907 to 1917. Since that time he has been a member of the firm of Barker and Wheeler, specializing in public utility regulation problems. He has been a member of the Vermont Advisory Engineers on Flood Control and consulting engineer for the Public Service Commission of Vermont, as well as advisory engineer for the Municipal Electric Utilities Association of New York and consultant for the department of railroads and telephones of the Province of Alberta, Canada. He also was evaluation consultant for the Tennessee Valley Authority. Mr. Barker is a member of the American Society of Mechanical Engineers, Phi Beta Kappa, and the Sons of the American Revolution.

Merwin McGehee Brandon (A'34, M'36, F'44) electrical engineer, Underwriter's Laboratories, Inc., New York, N. Y., has been appointed 1947–48 chairman of the AIEE committee on domestic and commercial applications. Born in Pinckneyville, Miss., November 14, 1898, Mr. Brandon received the degrees of bachelor of science in 1919 and electrical engineer in 1936 from Mississippi State College. After a year with the Westinghouse Electric Corporation, he joined the Underwriter's Laboratories Inc., in 1921

Harry Barker

M. M. Brandon

as assistant engineer. He was made special inspector in 1922, service engineer in 1924, and chief inspector in 1927. In 1928 he was appointed associate electrical engineer and in 1946 electrical engineer and as such has full responsibility and direction of the activities of the electrical department of the laboratories in Chicago, Ill.; New York; and San Francisco, Calif. He is a member of the International Association of Electrical Inspectors, the National Fire Protection Association, and Tau Beta Pi.

OBITUARY ● ● ● ●

William Elgin Wickenden (A '07, M '13, F '39) whose retirement as president of Case Institute of Technology, Cleveland, Ohio, became effective August 31, died September 1, 1947. Doctor Wickenden was AIEE president for 1945–46. Born December 24, 1882, in Toledo, Ohio, he was graduated from Denison University with the degree of doctor of science in 1904. Doctor Wickenden commenced his career as inspector at Mechanics Institute, Rochester, N. Y., and was a member of the faculty of the University of Wisconsin, Madison, from 1905 to 1909. He was named assistant professor of electrical engineering at Massachusetts Institute of Technology, Cambridge, in 1909, and associate professor in 1914. In 1918 he joined the Western Electric Company, New York, N. Y., as personnel manager, and in 1912 became assistant vice-president, American Telephone and Telegraph Company, New York. From 1923 until he became president of Case Institute in 1929, Doctor Wickenden was director of investigation of engineering education for the American Society for Engineering Education. As president of Case Institute he was responsible for the development of the evening division, a graduate school, and an organized program of research at the Institute. He was vice-president of AIEE for 1943–44, and had served on the AIEE committees on education, technical program, Student Branches, and Edison Medal, and was Cleveland Section chairman in 1936. Doctor Wickenden was honored with many degrees, receiving the degree of doctor of engineering from Lafayette College (1926), Worcester Polytechnic Institute (1927), Case Institute (1929), Rose Polytechnic Institute (1932); the doctor of science degree from Denison University (1928) and Bucknell University (1930); the degree of doctor of laws from Oberlin College (1930); the degree of doctor of humane letters from Otterbein College (1923). Widely known for his civic activities, Doctor Wickenden had been at various times a director of the Cleveland Chamber of Commerce, chairman of the Ohio Planning Board, chairman of the Ohio Labor Board, director of the Cleveland Community Fund, and a member of the Postwar Planning Council of Greater Cleveland, and of the Distribution Committee of the Cleveland Foundation. He was a director of the Apex Electrical and Manufacturing Company and the Equity Savings and Loan Company, a trustee of the Cleveland Clinic Foundation, and a member of the board of trustees of Case Institute and Lake Erie College. He had served as chairman of the American Council on Education, president of the Ohio College Association, president of the American Society for Engineering Education, and vice-president of the American Association for the Advancement of Science. He also was a member of the American Society of Mechanical Engineers, the American Academy of Political and Social Science, and the Cleveland Engineering Society. In 1935 he was awarded the Lamme Medal of the American Society for Engineering Education. He was the author of many articles on education and of "Illuminating and Photometry." Doctor Wickenden just had been nominated to serve as chairman of the AIEE committees on planning and co-ordination and on the Lamme Medal committee. He also recently had been appointed by the Engineers Joint Council as its representative on the United States Commission of the United Nations Educational, Scientific, and Cultural Organization.

Boyd Coe Dennison (A '06, M '23) professor of electrical engineering, Carnegie Institute of Technology, Pittsburgh, Pa., died August 19, 1947. Doctor Dennison, born in Hannibal, N. Y., September 9, 1881, was graduated from Cornell University in 1904 and received the degree of master of electrical engineering in 1908. He completed the test course of the General Electric Company, Schenectady, N. Y., and in 1905 returned to Cornell University, Ithaca, N. Y., as instructor in electrical engineering. He joined the faculty of Carnegie Institute in 1910 and was made full professor in 1929. Doctor Dennison had been consultant for Morris Knowles Company and the West Penn Power Company. He is the author of "Electrical Laboratory Experiments," and coauthor of "Electrical Problems." He served as chairman of the AIEE Pittsburgh Section in 1921 and also was a member of the American Society for Engineering Education, Tau Beta Pi, Eta Kappa Nu, and Sigma Xi.

Safford Kinkead Colby (A '03) vice-president in charge of research and advertising, Aluminum Company of America, Pittsburgh, Pa., died August 4, 1947. Mr. Colby was graduated from Rensselaer Polytechnic Institute with the degree of civil engineer. He joined the Pittsburgh Reduction Company, predecessor of the Aluminum Company of America, as assistant manager of its New York office in 1895. After becoming manager of the office, he was sent to the West Coast as company representative in 1905. He returned to New York in 1913 and became assistant general sales manager in 1915. He was elected president of the American Magnesium Corporation in 1920 and president of the American Body Company, a subsidiary of the Aluminum Company, in 1925. He was transferred to the Pittsburgh offices of the Aluminum Company in 1928 as chief of the sales promotion and advertising division. He was elected vice-president in 1931 and had supervised the company's research laboratories since 1937.

James J. Mullen (A '12, M '14, F '44) president, Moloney Electric Company, St. Louis, Mo., died June 23, 1947. Mr. Mullen was born in St. Louis, July 18, 1875. Prior to formation of the Moloney Electric Company in 1896, he was associated with the electric division of the Laclede Gas and Light Company of St. Louis. He became president of the Moloney Company in 1936. He served on many civic and industrial boards in the City of St. Louis.

Frank Gardner Willson (A '05, M '13) head of the department of applied electricity, Wentworth Institute, Boston, Mass., died July 29, 1947. Born in Bozeman, Mont., June 11, 1878, Mr. Willson was graduated from Montana State College and received the degree of bachelor of science in electrical engineering from the University of Wisconsin in 1903. He received his degree of master of science in 1913 from the University of Illinois, and was an instructor in electrical engineering at that institution from 1905 to 1913. Since 1913 he had been head of the department of applied electricity at Wentworth Institute. He was a member of the American Society for Engineering Education.

Luther Robert Nash (A '03, M '16) consulting engineer, Ridgefield, Conn., died August 10, 1947. Mr. Nash was born January 22, 1871, in Ridgefield, Conn., and received the degree of bachelor of science from Massachusetts Institute of Technology in 1894 and the degree of master of science at Harvard University in 1898. From 1895 to 1938, Mr. Nash had been associated with the Stone and Webster Engineering Corporation, New

York, N. Y. After holding the positions of design and construction engineer, manager of public utilities, and appraisal and rate expert, he became public relations manager in 1919. In 1932 he was made a vice-president of the company. In 1938 he established an independent consulting practice. He was the author of several books and articles on public utility and financial structures among which were "The Anatomy of Depreciation," "Economics of Public Utilities," and "Public Utility Rate Structures." He was a member of the Edison Electric Institute and the director of the Utilities Publication Committee.

Joseph Emory Sirrine (A '05, M '45) head, J. E. Sirrine and Company, Greenville, S. C., died August 7, 1947. Mr. Sirrine was born in Americus, Ga., December 9, 1872, and was graduated from Furman University. He founded his engineering firm in Greenville in 1902. Mr. Sirrine was chairman of Brandon Mills, Greenville; vice-president of four other South Carolina textile companies; and director of 19 other textile companies in the Southeast. During World War I he was chairman of the Price Fixing Committee for Cotton Textiles and during World War II served as a member of the Cotton Mill Industry Advisory Committee with the War Production Board. He was a member of the American Society of Mechanical Engineers and the American Society of Civil Engineers.

Frank T. Forster (A '16) member of the technical staff, power development department, Bell Telephone Laboratories, Inc., New York, N. Y., died May 11, 1947. Born June 10, 1883, Mr. Forster was graduated from Union College in 1905 with the degree of bachelor of engineering. He was associated with the General Electric Company, Schenectady, N. Y., from 1905 to 1923 and had worked with Doctor Charles Steinmetz. He joined the Bell System in 1923 and, as a member of the laboratory staff, had been engaged in the development of storage batteries and related apparatus. During World War II he worked on government projects, including tests of storage cells for aircraft and material substitution problems. He also had been concerned with the development of explosionproof devices for storage batteries.

MEMBERSHIP . . .

Applications for Election

Applications have been received at headquarters from the following candidates for election to membership in the Institute. Any member objecting to the election of any of these candidates should so inform the secretary before October 21, 1947, or December 21, 1947, if the applicant resides outside of the United States or Canada.

To the Grade of Member

Bowditch, F. T., National Carbon Co., Inc., Cleveland, Ohio
Carver, L. A., Rutgers Univ., New Brunswick, N. J.
Chase, A. S., Connecticut Lt. & Pr. Co., Devon, Conn.
Craig, R. L., Du Bois Engg. & Mfg. Co., Hammond, Ind.
Dawson, S. E., David Taylor Model Basin, Navy Dept., Washington, D. C.
Doria, O. P., College of Agriculture & Mechanic Arts, Mayaguez, Puerto Rico
Dunn, A. Y., Pacific Tel. & Tel. Co., Los Angeles, Calif.
Fiedler, G. H., Rochester Gas & Elec. Co., Rochester, N. Y.
Freeth, L. G., Intl. Standard Elec. Corp., New York, N. Y.
Hall, L. S., British Inst. of Engg. Technology, Sydney, N. S. W., Australia
Harben, E. B., Engr Section, Hq., Fourth Army, Ft. Sam Houston, Tex.
Hoyt, W. S., The Moore Co., Kansas City, Mo.
Hubrig, G. E., U. S. Rubber Co., North Kansas City, Mo.
Koger, G., General Elec. Co., Bridgeport, Conn.
Lyons, H., Natl. Bureau of Standards, Washington, D. C.
Mollerus, F. J., General Elec. Co., Hanford Engg. Works, Richland, Wash.
Morton, G. A., R. C. A. Laboratories, Princeton, N. J.
Pacanins, C., Compania Luz Electrica de Venezuela, Caracas, Venezuela, South America
Peterson, H. A., American Gas & Elec. Corp., New York, N. Y.
Pierce, F., Naval Ordnance Test Station, Pasadena, Calif.
Pinuela, I. de A., Sociedad Electro-Mecanica, Mexico City, Mexico.
Rothgeb, J. L., American Tel. & Tel. Co., Philadelphia, Pa.
Sawyer, C. C , 11 West Adams, Phoenix, Ariz.
Smith, S. W., Natl. Bureau of Standards, Washington, D. C.
Soucek, R., Westinghouse Elec. Corp., Los Angeles, Calif.
Vieth, W. G., Western Union Tel. Co., New York, N. Y.

26 to grade of Member

To Grade of Associate

United States, Canada, and Mexico

North Eastern

Adams, C. M., General Elec. Co., Pittsfield, Mass.
Bolgiano, R., Jr., Cornell University, Ithaca, N. Y.
Crotta. D. P., United Illuminating Co., New Haven, Conn.
Endsley, C. D., General Elec. Co., Schenectady, N. Y.
Gleeson, R. G., Plastic Wire & Cable Corp., Jewett City, Conn.
Hutton, E. W., General Elec. Co., Schenectady, N. Y.
Kimball, A. W., Western Elec. & Mfg. Co., Motor Div., Buffalo, N. Y.
Prater, M. P., Intl. Business Machines Corp., Endicott, N. Y.
Salisbury, C. R., General Elec. Co., Schenectady, N. Y.
VanRye, O., (re-election), New England Power Service Co., Boston, Mass.

2. Middle Eastern

Castner, P. J., Allis-Chalmers, Transformers Works, Pittsburgh, Pa.
Cox, G. R., Westinghouse Elec. Corp., East Pittsburgh, Pa.
Greshner, C. E., American Tel. & Tel. Co., Dayton, Ohio.
Haughawout, J. H., General Elec. Co., Erie, Pa.
Haynes, W. A., Jr., Navy Dept., Bureau of Ships, Washington, D. C.
Henry, S. D., Metropolitan Edison Co., Easton, Pa.
Hooper, C. K., Westinghouse Elec. Corp., Baltimore, Md.
Hutchings, W. S., New Jersey Zinc Co., Palmerton, Pa.
Jeffries, R. J., Johns Hopkins Univ., Baltimore, Md.
Langsdorf, B. F. T., Leeds & Northrup Co., Philadelphia, Pa.
O'Meara, W. J., (re-election) Atlantic Refining Co., Philadelphia, Pa.
Pergar, J. A., Westinghouse Elec. Co., East Pittsburgh, Pa,
Reid, W., Westinghouse Elec. Corp., East Pittsburgh, Pa.
Shafranek, R. J., Reliance Elec. & Engg. Co., Cleveland, Ohio
Tackaberry, W. R., General Elec. Co., Philadelphia, Pa.
Turner, J. S., Jr., Cincinnati Gas & Elec. Co., Cincinnati, Ohio

3. New York City

Gustavson, R. A., Kings County Lighting Co., Brooklyn, N. Y.
Leber, C. W., Jr., Standard Oil Development Co., Elizabeth, N. J.
Long, F. R., Engineering Societies Library, New York, N. Y.
Nichols, E. G., Allen B. Du Mont Laboratories, Inc., Clifton, N. J.
Parker, H. W., Sylvania Elec. Products, Inc., Kew Gardens, N. Y.
Rolfe, N., Consolidated Edison Co. of N. Y., New York, N. Y.
Seidel, C. M. (re-election), General Elec. Co., New York, N. Y.

4. Southern

Maupin. A. A., Jr., Carbide & Carbon Chemicals Corp., Oak Ridge, Tenn.
Nixon, D. R., Jr., Carolina Tel. & Tel. Co., Tarboro, N. C.
Postman, M. S., Gilbert L. Seay, Roanoke, Va.

5. Great Lakes

Don, A., Edw. Don & Co., Chicago, Ill.
Fossum, H., Public Utility Engg. & Serv. Co., Chicago, Ill.
Gleason, M. J., Western Elec., Hawthorne Plant, Chicago, Ill.
Honsberger, G. K., Consumers Power Co., Jackson, Mich.
Kenyon, C. D., General Elec. Co., Fort Wayne, Ind.
Killoran, J. L., Fisher Body Pontiac, Pontiac, Mich.
Kirk, I. M., Illinois Bell Tel. Co., Chicago, Ill.
Klaves, H. A., Commonwealth Edison Co., Chicago, Ill.
Metcalf, F. D., Ford Motor Co., Wayne, Mich.
Owen, G., Commonwealth Edison Co , Chicago, Ill.
Qureshi, M. A. A., c/o 608 S. Dearborn, Chicago, Ill.
Richardson, J. W., Allis-Chalmers Mfg. Co., Milwaukee, Wis.
Roeschlein. E. R., Center Point, Ind.
Rosal, P. M., Northern Indiana Public Service Co., Hammond, Ind.
White, V. J., Northwestern Univ. Technological Inst., Evanston, Ill.

6. North Central

Carpenter, E. B., Seminoe Dam, Wyo.

7. South West

Fernandez, C. M., Taller Dos Estrellas, Mexico, Mex.
Hagood, W. N., Freese & Nichols, Ft. Worth, Tex.
Hetzler, O. W., Kansas City Power Co., Kansas City, Kans.
Lago, G. V., Univ. of Missouri, Columbia, Mo.
Rector, A. H. (re-election), Burns & McDonnell Engg. Co., Kansas City, Mo.
Smith, E., Southwestern Bell Tel. Co., Abilene, Tex.
Weiser, L. D., Southwestern Bell Tel. Co., Topeka, Kans.

8. Pacific

Deggs, K. R., Stone & Webster Engg. Corp., Gardena, Calif.
Fowler, F. R. (re-election), Post Engineer, Presidio of San Francisco & Sub-Posts, Calif
Karrer, F., Sacramento Municipal Utility District, Sacramento, Calif.
Saini, R. M., War Dept., Army Transport Service, Fort Mason, Calif.

9. North West

Frans, W. D., U. S. Dept. of Interior, Bonneville Power Admin., Portland, Oreg.
Lonetto, P., Mountain States Tel. & Tel. Co., Salt Lake City, Utah

10. Canada

Allen, A. D., Allen Engineering Co., Ltd., Hamilton, Ontario, Canada
Williams, G. E., Amalgamated Elec. Corp., Ltd., Toronto, Ontario, Canada

Elsewhere

Bhargava, K. C., Hydro Electric Substation, Bulandshahar, U.P., India
Carbonell, A. E., Puerto Rico Water Resources Authority, Rio Piedras, Puerto Rico.
Goldstein, A., Brown, Boveri & Cie., Baden, Switzerland
Gomes, E. W., Tata Iron & Steel Ltd., Jamshedpur, India
Gondim, J. M., Cia Auxiliar de Empresas Electricas Brasileiras, Rio de Janeiro, Brazil, South America
Nelson, O. M., Demerara Electric Co., Ltd., Georgetown, B. G., South America
Santiago, A., Puerto Rico Water Resources Authority, Caguas, Puerto Rico
Torregrosa, E. R., Puerto Rico Iron Works, Inc., Ponce, Puerto Rico
Van, A. F., Pearl Harbor Naval Shipyard, Pearl Harbor, T. H.
Vina, F. A., Aeronautical Secretary Laboratories, London, England
Wild, A., English Elec. Co. Ltd., Stafford, England

Total to grade of Associate

United States, Canada, and Mexico, 67
Elsewhere, 11

Officers and Committees for 1947-48

Officers

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Junior Past President

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9	C. F. TERRELL	Seattle, Wash.
		(*Terms expire July 31, 1948*)
2	G. W. BOWER	Haddonfield, N. J.
4	J. H. BERRY	Norfolk, Va.
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8	D. I. CONE	San Francisco, Calif.
10	D. G. GEIGER	Toronto, Ontario, Canada
		(*Terms expire July 31, 1949*)

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	(*Terms expire July 31, 1948*)
J. M. FLANIGEN	Atlanta, Ga.
J. R. NORTH	Jackson, Mich.
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	(*Terms expire July 31, 1949*)
J. F. FAIRMAN	New York, N. Y.
R. T. HENRY	Buffalo, N. Y.
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	(*Terms expire July 31, 1950*)
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ELGIN B. ROBERTSON	Dallas, Tex.
	(*Terms expire July 31, 1951*)

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Secretary

H. H. HENLINE	New York, N. Y. (*Term expires July 31, 1948*)

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AUSTRALIA—V. J. F. Brain, Electricity Authority of New South Wales, Treasury Building, Bridge and Phillip Streets, Sydney, New South Wales.

BRAZIL—Richard H. Bowles, Sao Paulo Tramway Light and Power Company, Sao Paulo.

ENGLAND—A. P. M. Fleming, Metropolitan Vickers Electric Company, Trafford Park, Manchester 17.

INDIA, NORTHERN—N. Thornton, P.W.D., Electricity Branch, 11 Bahawalpur Road, Lahore, Punjab.

INDIA, SOUTHERN—N. N. Iengar, The Tata Power Company Ltd., Bombay House, Bruce Street, Fort, Bombay.

NEW ZEALAND—R. D. Neale, School of Engineering, Caterbury University College, Christchurch C. 1.

SWEDEN—Edy Velander, Royal Swedish Institute, Stockholm.

TRANSVAAL—Francis E. Ingham, Box 6067, Johannesburg, South Africa.

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J. Elmer Housley
A. C. Monteith
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Finance

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E. P. Yerkes

F. A. Norris, *secretary*, AIEE, 33 West 39th Street, New York 18, N. Y.

Planning and Co-ordination

(Chairman to be appointed to succeed W. E. Wickenden, deceased)

H. H. Henline, *secretary*, AIEE, 33 West 39th Street, New York 18, N. Y.

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J. F. Fairman
S. G. Hibben
B. M. Jones
Reginald L. Jones
T. G. LeClair
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H. H. Henline
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J. J. Orr
H. H. Race
C. F. Wagner

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J. W. Barker
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L. V. Berkner
C. R. Burrows
D. E. Chambers
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H. E. Edgerton
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J. A. Hutcheson
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Safety

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A. B. Smith, *vice-chairman* and *secretary*, National Electrical Manufacturers Association, 155 East 44th Street, New York 17, N. Y.

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Albrecht Naeter
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McNeely Du Bose
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H. E. Farrer, *secretary*, AIEE, 33 West 39th Street, New York 18, N. Y.

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Ex officio

Chairmen of working and co-ordinating committees of the Standards committee
Chairmen of AIEE technical committees
Chairmen of AIEE delegates on other standardizing bodies or sole representatives thereon
President, United States National Committee of the International Electrotechnical Commission

Technical Program

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C. S. Rich, *secretary*, AIEE, 33 West 39th Street, New York 18, N. Y.

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S. B. Crary
R. F. Danner
Truman S. Gray
S. G. Hibben
A. J. Krupy
J. J. Orr
Herbert Speight
M. J. Steinberg
Frank Thornton, Jr.
C. C. Whipple

Ex officio

Chairmen of:
- All technical committees
- Committee on education
- Committee on planning and co-ordination
- Committee on research
- Committee on safety
- Standards committee

Administration Group Committees

Administration Group Co-ordinating

J. F. Fairman, *chairman*, Consolidated Edison Company of New York, Inc., 4 Irving Place, New York 3, N. Y.

Chairmen of administration group committees

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E. D. Doyle, *vice-chairman*, Leeds and Northrup Company, 4901 Stenton Avenue, Philadelphia 44, Pa.

H. E. Farrer, *secretary*, AIEE, 33 West 39th Street, New York 18, N. Y.

R. W. Atkinson
Robin Beach
C. M. Laffoon
A. M. Musgrove

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C. W. Franklin
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I. F. Kinnard
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Constitution and Bylaws

Walter C. Smith, *chairman*, 680 Melville Avenue, Palo Alto, Calif.

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W. W. Lewis
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W. R. Smith, *chairman*, Public Service Electric and Gas Company, 80 Park Place, Newark 1, N. J.

H. H. Henline
D. A. Quarles

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C. R. Beardsley, *chairman*, Consolidated Edison Company of New York, Inc., 4 Irving Place, New York 3, N. Y.

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Membership

Tomlinson Fort, *chairman*, Westinghouse Electric Corporation, East Pittsburgh, Pa.

F. S. Black, *vice-chairman*, Potomac Electric Power Company, Tenth and E Streets, N.W., Washington 4, D. C.

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A. D. Brown
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E. P. Yerkes

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R. C. Horn (7)
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M. J. Lantz (9)
W. R. Way (10)

Ex officio

Chairmen of membership committees of all Sections

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G. W. Bower
M. Getting
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C. R. Jones
A. E. Knowlton
H. M. Turner

Transfers

D. E. Moat, *chairman*, Leeds and Northrup Company, 1800 Keith Building, Cleveland 15, Ohio.

Lloyd F. Hunt, *vice-chairman*, Southern California Edison Company Ltd., 601 West Fifth Street, Los Angeles 13, Calif.

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F. K. McCune
M. J. McHenry
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Ex officio

Chairmen of transfers committees of all Sections

Professional Group Committees

Professional Group Co-ordinating

T. G. LeClair, *chairman*, Commonwealth Edison Company, 72 West Adams Street, Chicago 90, Ill.

Chairmen of professional group committees

Code of Principles of Professional Conduct

Harry Barker, *chairman*, 11 Park Place, Room 1616, New York, N. Y.

D. D. Ewing
E. S. Fields
E. H. Flath
D. C. Jackson
R. D. Maxson
R. W. Sorensen

Edison Medal

Appointed by the president for term of five years

C. R. Freehafer, C. A. Powel, David Sarnoff (*Terms expire July 31, 1948*)
O. E. Buckley, A. E. Knowlton, H. E. Strang (*Terms expire July 31, 1949*)
C. V. Christie, Zay Jeffries, Harold Pender (*Terms expire July 31, 1950*)
C. A. Corney, S. M. Dean, *chairman*, I. M. Stein (*Terms expire July 31, 1951*)
Marvin W. Smith, H. S. Osborne, H. A. Winne (*Terms expire July 31, 1952*)

Elected by the board of directors from its own membership for term of two years

P. L. Alger, R. T. Henry, E. P. Yerkes (*Terms expire July 31, 1948*)
W. L. Everitt, J. F. Fairman, A. C. Monteith (*Terms expire July 31, 1949*)

Ex officio

B. D. Hull, president
W. I. Slichter, treasurer
H. H. Henline, secretary

Education

J. G. Tarboux, *chairman*, Cornell University, Ithaca, N. Y.

B. R. Teare, Jr., *vice-chairman*, Carnegie Institute of Technology, Pittsburgh, Pa.

J. A. Northcott, Jr., *secretary*, Engineering College, University of Notre Dame, Notre Dame, Ind.

H. W. Bibber
W. L. Cassell
G. F. Corcoran
E. E. Dreese
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H. E. Hartig
T. M. Linville
E. A. Loew
A. H. Lovell
T. C. McFarland
H. N. Muller
R. C. Putnam
Claire W. Ricker
R. W. Sorensen
C. E. Tucker
C. E. Tuites
E. A. Walker
R. W. Warner
S. Reid Warren
A. R. Zimmer

Charles LeGeyt Fortescue Fellowship

J. W. Barker, Ernst Weber (*Terms expire July 31, 1948*)
H. E. Strang, *chairman*, C. H. Willis (*Terms expire July 31, 1949*)
H. N. Muller, H. P. Sedwick (*Terms expire July 31, 1950*)

Lamme Medal

(Chairman to be appointed to succeed W. E. Wickenden, deceased)

H. L. Hazen, V. M. Montsinger, G. A. Waters (*Terms expire July 31, 1948*)
N. S. Hibshman, T. G. LeClair, A. C. Monteith (*Terms expire July 31, 1949*)
F. E. Harrell, J. B. Thomas (*Terms expire July 31, 1950*)

Management

Lee H. Hill, *chairman*, *Electrical World*, 330 West 42d Street, New York 18, N. Y.

K. P. Applegate
H. K. Breckenridge
F. W. Bush
W. L. Cisler
E. E. Hill
A. C. Monteith
E. L. Moreland
H. A. Peterson
H. E. Strang
O. Van Rye

Prizes, Award of Institute

H. M. Turner, *chairman*, Yale University, New Haven, Conn.

W. R. G. Baker
H. L. Davis, Jr.
S. G. Hibben
B. M. Jones
W. C. Kalb
J. J. Pilliod
Herbert Speight
M. J. Steinberg
C. G. Suits

Registration of Engineers

J. E. Hobson, *chairman*, Armour Research Foundation, 35 West 33rd Street, Chicago 16, Ill.

A. J. Krupy, *secretary*, Commonwealth Edison Company, 72 West Adams Street, Chicago 90, Ill.

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L. O. Campbell
J. H. Foote
N. L. Freeman
L. A. Griffith
J. D. Guillemette
F. W. L. Hill
H. B. Joyce
R. E. Kistler
K. B. McEachron
R. E. Muehlig
J. G. Patterson
W. W. Perry
Elgin B. Robertson
L. M. Robertson

Student Branches

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E. M. Strong, *vice-chairman*, Cornell University, Ithaca, N. Y.

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P. L. Hoover
A. H. Howell
Everett S. Lee
J. H. Kuhlmann
W. H. Pickering
L. T. Rader
R. W. Warner
B. S. Willis
C. R. Wischmeyer

Ex officio

Student Branch counselors

Technical Committees

Power Co-ordinating Committee

M. J. Steinberg, *chairman*, Consolidated Edison Company of New York, Inc., 4 Irving Place, New York, N. Y.

H. W. Collins, *vice-chairman*
R. T. Henry
Frank Thornton, Jr.

Ex officio

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Power Generation

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F. L. Reinmann
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G. R. Woodman

Rotating Machinery

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T. M. Linville
T. C. Lloyd
M. J. Lowenberg
C. Lynn
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C. G. Veinott
C. Woods

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K. B. Hoffman
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S. F. French
W. L. Hiscox
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S. L. Smith
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G. W. Gerell
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E. R. Whitehead
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Boston	1	Feb. 13, '03	766	W. Irving Middleton	L. F. Cleveland	Northeastern University, 360 Huntington Ave., Boston 15, Mass.
Central Indiana	5	Jan. 12, '12	197	W. H. Bollinger	G. F. Switzer	40 North Irwin, Indianapolis 1, Minnesota
Chicago	5	1893	1,381	J. E. Hobson	F. D. Troxel	Sargent & Lundy, 140 S. Dearborn St., Chicago 3, Illinois
Cincinnati	2	June 30, '20	198	Howard E. Barnett	W. H. McNutt	Westinghouse Elec. Corp., 207 W. Third St., Cincinnati 2, Ohio
Cleveland	2	Sept. 27, '07	583	O. N. Jones	R. L. Oetting	General Elec. Co., Nela Park, Cleveland 12, Ohio
Columbus	2	Mar. 17, '22	116	Robert C. McMaster	Edward J. Ramaley	Battelle Memorial Institute, 505 King Ave., Columbus 1, Ohio
Connecticut	1	Apr. 16, '21	475	Chester D. Hewitt	Elmer G. Horton	Westinghouse Elec. Corp., P.O. Box 1817, New Haven 8, Conn.
Dayton	2	June 9, '43	273	W. A. Barden	L. H. Fox	2008 Rugby Road, Dayton 6, Ohio
Denver	6	May 18, '15	325	L. R. Patterson	Evan R. Jones	Mountain States Tel. & Tel. Co., Box 960, Denver 1, Colo.
East Tennessee	4	Sept. 2, '36	290	J. J. Hill	I. M. Barnes	Tenn. Valley Authority, Power Bldg., Chattanooga 2, Tenn.
Erie	2	Jan. 11, '18	110	M. W. Kitzmiller	F. T. Parker	2304 Bird Drive, Erie, Pa.
Florida	4	Jan. 28, '31	181	C. H. Summers	Robert M. Garth	Public Works Dept., Naval Air Station, Jacksonville, Fla.
Fort Wayne	5	Aug. 14, '08	124	M. L. Schmidt	C. J. Herman	General Elec. Co., 1435 Broadway, Fort Wayne 2, Indiana
Georgia	4	Jan. 14, '04	193	Marion S. Johnson	James R. Raney	Georgia Power Co., 75 Marietta St., N.W., Atlanta, Ga.
Houston	7	Aug. 7, '28	227	H. Lee Miller	W. O. Ray	6647 Lindy Lane, Houston 12, Tex.

(continued on page 1030)

Sections (continued)

Name	District	When Organized	Membership Aug. 1, 1947	Chairman	Secretary	Secretary's Address
Illinois Valley	5	June 30, '45	95	G. H. Duff	R. P. Pfeiffer	2318 Missouri Ave., Peoria 4, Ill.
Iowa	5	June 29, '29	115	W. L. Cassell	John V. Gebuhr	1128 Oak Park Ave., Des Moines 13, Iowa
Ithaca	1	Oct. 15, '02	112	W. W. Perry	H. L. Livingood	N. Y. State Elec. & Gas Corp., 62 Henry St., Binghamton, N. Y.
Kansas City	7	Apr. 14, '16	221	T. L. Jones	P. A. Haas	Board of Public Utilities, 6th & Ann Ave., Kansas City 16, Kansas
Lehigh Valley	2	Apr. 16, '21	244	F. W. Smith	A. L. Price	173 S. Church St., Hazleton, Pa.
Los Angeles	8	May 19, '08	1,027	H. D. Strong	Eugene L. Bettannier	City Hall, Room 302, 100 North Garfield Ave., Pasadena 1, Calif.
Louisville	4	Oct. 15, '26	104	Harry Hadsel	M. G. Northrop	Speed Scientific School, Univ. of Louisville, Louisville 8, Ky.
Lynn	1	Aug. 22, '11	255	M. A. Princi	Richard G. Slauer	Sylvania Elec. Products Co., Inc., 126 Washington St., Salem, Mass.
Madison	5	Jan. 8, '09	67	Berhnard C. Lueders	Lawrence F. Kehoe	Dairyland Power Co-operative, Rivoli Bldg., LaCrosse, Wis.
Mansfield	2	Mar. 6, '39	66	H. E. Edwards	E. C. Ryan	425 Overlook Road, Mansfield, Ohio
Maryland	2	Dec. 16, '04	512	Edwin Hansson	F. H. Rogers	Meter & Installation Dept., Consolidated Gas & Elec. Lt. Pr. Co., Baltimore 3, Md.
Memphis	4	May 22, '30	139	Maury G. Sifford	James R. Morton	Memphis Light, Gas & Water Div., Box 388, Memphis 1, Tenn.
Mexico	7	June 29, '22	209	Manuel M. DeLascurain	George B. Doughman	Calle de la Palma 33, Apartado 2530 Mexico, D. F., Mexico
Michigan	5	Jan. 13, '11	652	A. W. Rauth	M. R. Horne	22187 W. Michigan Ave., Dearborn, Mich.
Milwaukee	5	Feb. 11, '10	553	L. C. Aicher	E. H. Fredrick	Allis-Chalmers Mfg. Co., Milwaukee 1, Wisconsin
Minnesota	5	Apr. 7, '02	212	John H. Merriman	Lincoln A. Rietow	Control Corporation, Minneapolis 14, Minnesota
Montana	9	June 24, '31	85	W. H. Blankmeyer	D. E. Kampschror	Westinghouse Elec. Corp., 52 East Broadway, Butte, Montana
Montreal	10	Apr. 16, '43	262	H. W. Haberl	N. L. Morgan	Northern Elec. Co. Ltd., 1261 Shearer St., Montreal, Que., Canada
Muscle Shoals	4	Feb. 18, '38	24	W. E. Lindemann	C. R. Goodroe	TVA, Elec. Lab. and Test Div., Wilson Dam, Ala.
Nebraska	6	Jan. 21, '25	72	R. L. Schact	James Pros	General Elec. Supply Corp., 914 N. 18th St., Omaha 2, Nebr.
New Mexico–West Texas	7	Mar. 7, '40	82	John A. Davis, Jr.	Lee R. Hammond, Jr.	2910 Grant Ave., El Paso, Texas
New Orleans	4	Dec. 8, '33	231	W. D. Stroud	E. I. Blanchard	Louisiana Power & Light Co., 433 Metairie Rd., New Orleans 20, Louisiana
New York	3	Dec. 10, '19	4,509	W. J. Barrett	D. W. Taylor	Public Service Elec. & Gas Co., 80 Park Place, Newark 1, N. J.
Niagara Frontier	1	Feb. 10, '25	268	H. C. Lindberg	B. S. Rice	Buffalo Niagara Elec. Corp., 500 Elec. Bldg., Buffalo 3, N. Y.
North Carolina	4	Mar. 21, '29	187	E. W. Olschner	C. R. Jones	Carolina Telephone & Telegraph Co., Tarboro, N. C.
North Texas	7	May 18, '28	335	Wendell C. Fowler	J. M. Hagler	Southwestern Bell Telephone Co., 810 Telephone Bldg., Dallas 2, Texas
Oklahoma City	7	Feb. 16, '22	159	Frank P. Kasper	Harold L. Pickens	Allis-Chalmers Mfg. Co., 901 West Grand, Oklahoma City 4, Okla.
Panhandle	7			Earl R. Price	George W. Dupree	Southwestern Public Service Company, Amarillo, Texas
Philadelphia	2	Feb. 18, '03	1,180	W. R. Clark	H. H. Sheppard	Rumsey Electric Co., 1007 Arch St., Philadelphia 7, Pa.
Pittsburgh	2	Oct. 13, '02	814	A. C. Monteith	H. H. Wagner	Pennsylvania Transformer Co., 808 Ridge Ave., Pittsburgh 12, Pa.
Pittsfield	1	Mar. 25, '04	225	W. S. Fielding	F. H. Judkins	General Elec. Co., 100 Woodlawn Ave., Pittsfield, Mass.
Portland	9	May 18, '09	382	M. D. Duffy	M. M. Ewell	Westinghouse Elec. Corp., 914 U. S. Nat'l. Bank Bldg., 309 S. W. 6th Ave., Portland 4, Oregon
Providence	1	Mar. 12, '20	127	Edward R. Coop	George E. Andrews, Jr.	Engineering Dept., Narragansett Elec. Co., Providence 1 R. I.
Rochester	1	Oct. 9, '14	180	A. F. Martin	C. G. Plomasen	285 Cooper Road, Rochester 12, N. Y.
Rock River Valley	5		48	Kenneth M. Sparrow	Warner A. Johnson	1222 South Chicago, Freeport, Illinois
St. Louis	7	Jan. 14, '03	413	E. S. Rehagen	R. N. Slinger	General Elec. Co., 112 N. 4th St., St. Louis, Mo.
San Diego	8	Jan. 18, '39	124	George E. Jenner	Joseph F. Sinnott	2265 Juan St., San Diego 3, Calif.
San Francisco	8	Dec. 23, '04	951	H. E. Becker	O. A. Gustafson	General Elec. Co., 235 Montgomery St., San Francisco 4, Calif.
Schenectady	1	Jan. 26, '03	764	B. H. Caldwell	J. C. Page	Central Station Engg. Div., General Elec. Co., Schenectady 5, N. Y.
Seattle	9	Jan. 19, '04	330	H. M. Gustafson	W. J. Mosley	Puget Sound Power & Light Co., Seattle 1, Washington
Sharon	2	Dec. 11, '25	150	R. L. Brown	E. W. Tipton	R. F. D. 2, Sharon Mercer Road, Sharon, Pa.
Shreveport	4					
South Bend	5	Feb. 26, '41	85	Arthur J. Quigley	John W. Leadbetter	314 Peashway St., South Bend 17, Indiana
South Carolina	4	Mar. 2, '40	66	Charles O. Warren	Max G. Toole	P. O. Box 42, Navy Yard, Charleston 1, S. C.
South Texas	7	May 23, '30	101	S. R. Friedsam	L. L. Antes	700 East 23½ St., Austin 22, Texas
Spokane	9	Feb. 14, '13	142	H. C. Glaze, Jr.	T. W. MacLean	Washington Water Power Co., 825 West Trent Ave., Spokane 6, Washington
Springfield	1	June 29, '22	78	Frederick G. Webber	Weyman E. Maxwell	77 Ellsworth Ave., Springfield 8, Mass.
Syracuse	1	Aug. 12, '20	187	W. C. Jenkins	L. M. Moore	Central N. Y. Power Corp., 300 Erie Blvd. West, Syracuse 2, N. Y.
Toledo	2	June 3, '07	97	Conrad H. Johnson	Walter M. Campbell	2145 Central Grove Ave., Toledo, Ohio
Toronto	10	Sept. 30, '03	513	T. C. D. Churchill	H. R. Osborne	Ferranti Elec. Ltd., Mount Dennis, Toronto, Ont., Canada
Tulsa	7	Oct. 1, '37	123	L. F. Rylander	Dick Ray	Nelson Elec. Mfg. Co., 319 North Detroit, Tulsa, Okla.
Urbana	5	Nov. 25, '02	74	W. E. Miller	H. N. Hayward	Dept. of Elec. Engg., University of Illinois, Urbana, Illinois
Utah	9	Mar. 9, '17	103	D. R. Hoopes	John A. McDonald	General Elec. Co., P. O. Box 779, Salt Lake City, Utah
Vancouver	10	Aug. 22, '11	143	Henry W. Smith	W. J. Lind	4093 West 13th Ave., Vancouver, B. C., Canada
Virginia	4	May 19, '22	180	Wm. A. Murray	Wm. T. Jones	506 Richmond Trust Bldg., Richmond 19, Va.
Washington	2	Apr. 9, '03	769	Norman B. Ames	Ralph D. Bennett	Naval Ordnance Lab., Navy Yard, Washington, D. C.
West Virginia	2	Apr. 9, '40	96	R. F. Norwood	C. M. Hunt	P. O. Box 1906, Charleston 27, W. Va.
Wichita	7	Sept. 16, '37	84	R. Richard Jenner	C. W. Halferty	Kansas Gas & Elec. Co., 201 N. Market St., Wichita 1, Kansas
Worcester	1	Feb. 18, '20	78	Donald G. MacMillan	Wilfred G. Coleman	General Elec. Co., 507 Main St., Worcester 8, Mass.
Total Sections	80		25,336			

Geographical District Executive Committees

	District	Chairman (Vice-President, AIEE)	Secretary (District Secretary)	Chairman, District Committee on Student Activities
1	North Eastern	E. W. Davis, Simplex Wire & Cable Co., 79 Sidney St., Cambridge 39, Mass.	Victor Siegfried, American Steel & Wire Co., Worcester 7, Mass.	E. R. McKee, University of Vermont, Burlington, Vt.
2	Middle Eastern	G. W. Bower, 127 Hopkins Ave., Haddonfield, N. J.	A. C. Muir, Berwind-White Coal Mining Co., 1138 Commercial Trust Bldg., Philadelphia 2, Pa.	P. L. Hoover, Case School of Applied Science Cleveland 6, Ohio
3	New York City	O. E. Buckley, Bell Telephone Laboratories, Inc., 463 West St., New York 14, N. Y.	J. L. Callahan, R.C.A. Laboratories, Radio Corporation of America, 66 Broad St., New York 4, N. Y.	Harry Baum, College of the City of New York, 139th St. & Convent Ave., New York, N. Y.
4	Southern	J. H. Berry, Electric Dept., Virginia Electric and Power Co., Norfolk 1, Va.	C. B. Galphin, 1028 Central Ave., Charlotte 4, N. C.	W. O. Leffell, University of Tennessee, Knoxville, Tenn.
5	Great Lakes	T. G. LeClair, Commonwealth Edison Co., 72 W. Adams St., Chicago 90, Ill.	N. C. Pearcy, Public Utility Engg. & Service Corp., 231 S. La Salle St., Chicago 4, Ill.	Robert E. Beam, The Technological Institute, Northwestern University, Evanston, Ill.
6	North Central	I. M. Ellestad, Northwestern Bell Telephone Co., 823 Telephone Bldg., Omaha 2, Nebr.	M. L. Burgess, Westinghouse Electric Corp., 117 N. 13th St., Omaha 2, Nebr.	John E. Martin, University of Denver, Denver, Colo.
7	South West	R. F. Danner, Oklahoma Gas & Electric Co., Oklahoma City 1, Okla.	W. B. Stephenson, Southwestern Bell Telephone Co., Oklahoma City 2, Okla.	Arthur S. Brown, University of Arkansas, Fayetteville, Ark.
8	Pacific	D. I. Cone, Pacific Tel. & Tel. Co., 140 New Montgomery St., San Francisco 5, Calif.	B. D. Dexter, 245 Market St., San Francisco, Calif.	Wm. J. Warren, University of Santa Clara, Santa Clara, Calif.
9	North West	C. F. Terrell, Puget Sound Power & Light Co., 860 Stuart Bldg., Seattle, Wash.	C. H. Cutter, 814 Securities Bldg., Seattle 1, Wash.	H. F. Lickey, Washington State College, Pullman, Wash.
10	Canada	D. G. Geiger, Bell Telephone Co. of Canada Ltd., 76 Adelaide St. W., Toronto 1, Ont.	J. Taylor Fisher, 76 Adelaide St. West, Toronto 1, Ont.	W. B. Coulthard, University of British Columbia, Vancouver, B. C.

Note: Each District executive committee includes also the chairmen and secretaries of all Sections within the District and the District vice-chairman of the AIEE membership committee.

Subsections

Name	Chairman	Secretary	Secretary's Address
Albuquerque (New Mexico–West Texas Section)			
Baton Rouge (New Orleans Section)	A. K. Ramsey, Jr.	F. R. Adams	Southern Bell Tel. & Tel. Co., 555 Florida Street, Baton Rouge 8, La.
Binghamton Area (Ithaca Section)	M. F. Skinker	K. S. Koon	I. B. M. Corp., Endicott, N. Y.
Boulder Dam (Los Angeles Section)	C. P. Christensen	Wade H. Taylor	Bureau of Reclamation, Boulder City, Nevada
Canton (Akron Section)	R. C. Wey	H. E. Rue	310 Fairview St., North Canton, Ohio
Casper, Wyo. (Denver Section)	B. A. Fleshman	C. R. McLean	Mountain States Power Co., Casper, Wyo.
Charleston (South Carolina Section)	Dean H. Davis	Max G. Toole	P. O. Box 42, Navy Yard, Charleston, S. C.
Charlotte (North Carolina Section)	Russell Ranson	J. S. Myers	P. O. Box 1969, Charlotte, N. C.
Corpus Christi (South Texas Section)	George A. Mills		
Florida West Coast (Florida Section)	I. C. Matheson		
Fort Worth (North Texas Section)	Leland B. Bass	J. L. Candry	Texas Elec. Service Co., Electric Bldg., Fort Worth 2, Texas
Fox River Valley (Milwaukee Section)	Arthur E. Carlson	Jesse W. Pomazal	708 East Hancock Street, Appleton, Wis.
Fresno (San Francisco Section)	J. P. Price		
Great Falls (Montana Section)	Dennis A. Johnson	Sidney E. McArthur	Montana Power Co., Morony Dam, Great Falls, Montana
Hamilton (Toronto Section)	W. J. Porter	C. E. Moorhouse	Canadian Westinghouse Co., Ltd., Hamilton, Ontario, Canada
Hampton Roads (Virginia Section)	A. I. Osborne	Hayward W. Evans	Virginia Elec. & Power Co., Norfolk, Va.
Hudson Valley (New York Section)	H. A. McLaughlin	T. F. X. Vail	Central Hudson Gas & Elec. Corp., South Road, Poughkeepsie, N. Y.
Jacksonville (Florida Section)	M. L. Barre		
Lake Charles (New Orleans Section)	G. V. Cooper	J. W. Kirkland	Gulf States Utilities Co., 314 Broad St., Lake Charles, Florida
Lancaster–York (Maryland Section)	J. L. Stauffer	W. H. Freund	R. C. A. Mfg. Co., Lancaster, Pa.
Mayaguez (New York Section)	Miguel Wiewall, Jr.	Modesto I. Beauchamp	College of A. & M. Arts, Univ. of Puerto Rico, Mayaguez, Puerto Rico
Miami (Florida Section)	P. J. Carlin		
New Jersey (New York Section)	Leland F. Stone	L. J. Lunas	Westinghouse Electric Corp., 95 Orange Street, Newark, N. J.
Niagara (Toronto Section)	J. I. Gram	W. G. Barr	1888 Main Street, Niagara Falls, Ontario, Canada
Niagara Falls (Niagara–Frontier Section)	J. M. Davidson	J. A. Persson	368 Spruce Avenue, Niagara Falls, N. Y.
Ottawa (Montreal Section)	G. R. Davis	R. M. Morris	National Research Council, Sussex St., Room 70, Ottawa, Ontario, Canada
Quad–Cities (Iowa Section)	R. B. Miller	E. C. Lister	Stanley Engineering Co., Muscatine, Iowa
Richmond (Virginia Section)	P. R. Spracher	Bruce C. Halsted	Allis-Chalmers Mfg. Co., Richmond Trust Bldg., Richmond, Va.
Sacramento (San Francisco Section)	James C. Coombs	James R. Miller	3391—3rd Avenue, Sacramento, Calif.
Saginaw Valley (Michigan Section)	Gordon S. Marvin	George Grant, III	2115 Gratiot Ave., Saginaw, Michigan
San Juan (New York Section)	Ivan Megwinoff	Victor M. Cataldo	Flores Street 155, Santurce, Puerto Rico
Shasta (San Francisco Section)	Louis M. VanMeter		
West Central Texas (North Texas Section)	Don W. Whitaker	E. N. Mitchell	General Meter Dept., West Texas Utilities, Abilene, Texas
Wilmington (Philadelphia Section)	N. O. Rowe	Elmer W. Randall	E. I. du Pont de Nemours & Co., Wilmington, Del.
Zanesville (Columbus Section)	W. B. Abele	Robert P. Thompson	329 Putnam Avenue, Zanesville, Ohio

Student Branches

Name and Location	District	Counselor (Member of Faculty)
Akron, University of, Akron, Ohio	2	A. J. Fairburn
Alabama Polytechnic Institute, Auburn	4	
Alabama, University of, University	4	William J. Miller
Alberta, University of, Edmonton, Canada	10	R. E. Phillips
Arizona, University of, Tucson	8	J. C. Clark
Arkansas, University of, Fayetteville	7	A. S. Brown
British Columbia, University of, Vancouver, Canada	10	W. B. Coulthard
Brooklyn, Polytechnic Inst. of, Brooklyn, N. Y. (Day)	3	F. Wahlers
(Evening)	3	Anthony B. Giordano
Brown University, Providence, R. I.	1	F. N. Tompkins
Bucknell University, Lewisburg, Pa.	2	George Irland
California Institute of Technology, Pasadena	8	William H. Pickering
California, University of, Berkeley	8	R. M. Saunders
Carnegie Institute of Technology, Pittsburgh, Pa.	2	D. W. VerPlanck
Case Institute of Technology, Cleveland, Ohio	2	P. L. Hoover
Catholic University of America, Washington, D. C.	2	T. J. MacKavanagh
Cincinnati, University of, Cincinnati, Ohio	2	A. C. Herweh
Clarkson College of Technology, Potsdam, N. Y.	1	Alfred R. Powers
Clemson Agricultural College, Clemson, S. C.	4	F. T. Tingley
Colorado A and M College, Ft. Collins	6	C. F. Chinburg
Colorado, University of, Boulder, Colo.	6	Platt Wicks
Columbia University, New York, N. Y.	3	W. A. LaPierre
Connecticut, University of, Storrs	1	G. S. Timoshenko
Cooper Union, New York, N. Y.	3	Norman L. Towle
Cornell University, Ithaca, N. Y.	1	B. K. Northrup
Delaware, University of, Newark	2	R. E. Kuehn
Denver, University of, Denver, Colo.	6	John E. Martin
Detroit, University of, Detroit, Mich.	5	H. O. Warner
Drexel Institute of Technology, Philadelphia, Pa.	2	F. C. Powell
Duke University, Durham, N. C.	4	Otto Meier, Jr.
Florida, University of, Jacksonville	4	F. H. Pumphrey
George Washington University, Washington, D. C.	2	Milton K. Akers
Georgia School of Technology, Atlanta, Ga.	4	H. B. Duling
Harvard University, Cambridge, Mass.	1	John C. Fisher
Idaho, University of, Moscow	9	J. H. Johnson
Illinois Institute of Technology, Chicago	5	E. T. B. Gross
Illinois, University of, Urbana	5	E. A. Reid
Navy Pier Div., Chicago		
Iowa State College, Ames	5	B. S. Willis
Iowa, University of, Iowa City	5	E. B. Kurtz
Johns Hopkins University, Baltimore, Md.	2	F. Hamburger, Jr.
Kansas State College, Manhattan	7	Joe E. Ward
Kansas, University of, Lawrence	7	David D. Robb
Kentucky, University of, Lexington, Ky.	4	Brinkley Barnett
Lafayette College, Easton, Pa.	2	Finley W. Smith
Lehigh University, Bethlehem, Pa.	2	J. L. Beaver
Louisiana State University, Baton Rouge	4	W. D. Morris
Louisville, University of, Louisville, Ky.	4	S. T. Fife
Maine, University of, Orono	1	W. J. Creamer
Manhattan College, New York, N. Y.	3	Robert T. Weil
Marquette University, Milwaukee, Wis.	5	E. W. Kane
Maryland, University of, College Park	2	L. J. Hodgins
Massachusetts Institute of Technology, Cambridge	1	E. W. Boehne
Michigan College of Mining and Tech., Houghton	5	G. W. Swenson
Michigan State College, East Lansing	5	J. A. Strelzoff
Michigan, University of, Ann Arbor	5	J. S. Gault
Milwaukee School of Engineering, Milwaukee, Wis.	5	R. J. Ungrodt
Minnesota, University of, Minneapolis	5	J. H. Kuhlmann
Mississippi State College, State College	4	Harry C. Simrall
Missouri School of Mines and Metallurgy, Rolla	7	I. H. Lovett
Missouri, University of, Columbia	7	Clifford M. Wallis
Montana State College, Bozeman	9	G. D. Sheckels
Nebraska, University of, Lincoln	6	C. W. Rook
Nevada, University of, Reno	8	I. J. Sandorf
Newark College of Engineering, Newark, N. J.	3	Wm. Jordan, 3rd.

Total Branches........127

Name and Location	District	Counselor (Member of Faculty)
New Hampshire, University of, Durham, N. H.	1	Wm. B. Nulsen
New Mexico State College, State College	7	
New Mexico, University of, Albuquerque	7	E. C. Bickley
New York, College of the City of, New York, N. Y.	3	Harry Baum
New York University, New York	3	S. G. Lutz
North Carolina State College, Raleigh	4	W. D. Stevenson, Jr.
North Dakota State Agricultural College, Fargo	5	Harry S. Dixon
North Dakota, University of, Grand Forks	5	J. C. Hogan
Northeastern University, Boston, Mass.	1	R. G. Porter
Northwestern University, Evanston, Ill.	5	R. Beam
Norwich University, Northfield, Vt.	1	F. A. Spencer
Notre Dame, University of, Notre Dame, Ind.	5	L. F. Stauder
Ohio Northern University, Ada	2	Ralph E. Walter
Ohio State University, Columbus	2	E. E. Kimberly
Ohio University, Athens	2	D. B. Green
Oklahoma Agricultural and Mechanical College, Stillwater	7	Albrecht Naeter
Oklahoma, University of, Norman	7	Gerald Tuma
Oregon State College, Corvallis	9	M. J. Kofoid
Pennsylvania State College, State College	2	A. P. Powell
Pennsylvania, University of, Philadelphia	2	Kenneth Fegley
Pittsburgh, University of, Pittsburgh, Pa.	2	R. C. Gorham
Pratt Institute Brooklyn, N. Y.	3	Donald H. Wright
Princeton University, Princeton, N. J.	2	J. E. Paul
Puerto Rico, University of, Mayaguez, P. R.	3	Miguel Wiewall, Jr.
Purdue University, Lafayette, Ind.	5	C. R. Nichols
Rensselaer Polytechnic Institute Troy, N. Y.	1	E. D. Broadwell
Rhode Island State College, Kingston	1	W. C. Birtwell
Rice Institute, Houston, Tex.	7	J. S. Waters
Rose Polytechnic Institute, Terre Haute, Ind.	5	C. C. Knipmeyer
Rutgers University, New Brunswick, N. J.	3	P. S. Creager
Santa Clara, University of, Santa Clara, Calif.	8	W. J. Warren
South Carolina, University of, Columbia	4	Samuel Litman
South Dakota State College, Brookings	5	Wm. H. Gamble
South Dakota State School of Mines and Technology, Rapid City	6	J. O. Kammerman
Southern California, University of, Los Angeles	8	Rodney C. Lewis
Southern Methodist University, Dallas, Tex.	7	J. W. Tatum
Stanford University, Stanford University, Calif.	8	W. G. Hoover
Stevens Institute of Technology, Hoboken, N. J.	3	Wm. L. Sullivan
Swarthmore College, Swarthmore, Pa.	2	Howard M. Jenkins
Syracuse University, Syracuse, N. Y.	1	Leroy A. Mullin
Tennessee, University of, Knoxville	4	W. O. Leffell
Texas, Agricultural and Mechanical College, of College Station	7	N. F. Rode
Texas Technological College, Lubbock	7	C. V. Bullen
Texas, University of, Austin	7	A. J. McCrocklin, Jr.
Toronto, University of, Toronto, Ontario, Canada	10	L. S. Lauchland
Tufts College, Medford, Mass.	1	A. H. Howell
Tulane University, New Orleans, La.	4	Allan S. Pincus
Union College, Schenectady, N. Y.	1	H. W. Bibber
Utah, University of, Salt Lake City	9	O. C. Haycock
Vanderbilt University, Nashville, Tenn.	4	S. R. Schealer
Vermont, University of, Burlington	1	E. R. McKee
Villanova College, Villanova, Pa.	2	Harry S. Bueche
Virginia Military Institute, Lexington	4	J. S. Jamison
Virginia Polytechnic Institute, Blacksburg	4	Claudius Lee
Virginia, University of, Charlottesville	4	L. R. Quarles
Washington, State College of, Pullman	9	H. F. Lickey
Washington, University of, Seattle	9	V. L. Palmer
Washington University, St. Louis, Mo.	7	Pierre M. Honnell
Wayne University, Detroit, Mich.	5	
West Virginia University, Morgantown	2	A. H. Forman
Wisconsin, University of, Madison	5	John C. Weber
Worcester Polytechnic Institute, Worcester, Mass.	1	D. C. Alexander
Wyoming, University of, Laramie	6	R. O. Trueblood
University, New Haven, Conn.	1	

OF CURRENT INTEREST

National Electronics Conference Program

More than 80 technical papers will be presented at the National Electronics Conference, which is to be held at the Edgewater Beach Hotel, Chicago, Ill., November 3–5, 1947. Several nontechnical addresses are scheduled as well, such as,

Keynote address by **President G. D. Stoddard**, University of Illinois

"Electronics Comes of Age," by Doctor L. E. Berkner, Joint Research and Development Board

Luncheon speaker, W. Evans, vice-president, Westinghouse Electric Company

"An American Engineering Association," B. D. Hull, chief engineer, Southern Bell Telephone Company, president AIEE

The first three speeches will be presented on Monday, November 3, and President Hull's address will be delivered at the luncheon on Tuesday, November 4, 1947.

The tentative list of technical papers scheduled follows.

MONDAY, NOVEMBER 3

Noise Suppression and Distortion

Dynamic Noise Suppressor, **H. H. Scott**, Technology Instrument Corporation

Intermodulation Method of Distortion Measurement, **W. J. Warren** and **W. R. Hewlett**, Hewlett-Packard Company

S/N Ratio in A-M Receivers, **E. C. Fubini** and **D. C. Johnson**, Airborne Instruments Laboratory, Inc.

Corona Discharge at High Altitude and Low Temperature, **H. J. Dana**, State College of Washington

Electronic Instrumentation

Chairman: **M. F. Behar**, editor of *Instruments*

Self-Balancing Thermistor Bridge, **A. C. Bath**, Bendix Radio Corporation

Variable Ratio Inductance Bridges and Networks, **Paul Glass** and **Sylva May Dushkes**, Askania Regulator Company

A Miniature Gastro-manometer for Electrical Recording, **H. C. Roberts**, University of Illinois

Short-Time Oscillography, **Jean V. Lebacqz**, Johns Hopkins University

Coaxial Elements and Microwaves

Bead Supported Coaxial Attenuator (4,000 to 10,000 mc), **John W. E. Griemsmann** and **Herbert J. Carlin**, Microwave Research Institute, Polytechnic Institute of Brooklyn

Wave Propagation in Beaded Lines, **R. E. Beam**, Northwestern University

Coaxial Elements and Connectors, **W. R. Thurston**, General Radio Company

Broadband Matching of Impedances, **R. M. Fano**, Massachusetts Institute of Technology

Broadband-Bolometer-Type Ultrahigh-Frequency Power Meters, **M. J. Di Toro**, Polytechnic Institute of Brooklyn

Operation of Electronic Research

Chairman: **J. E. Hobson**, Armour Research Foundation

Organization and Operation of Electronic Research, **R. M. Bowie**, Sylvania Electric Company

Electronic Research in the University, **L. T. DeVore**, University of Illinois

Electronic Research in the Research Institute, **C. E. Zeigler**, Midwest Research Institute

Electronic Research in the Government Service, **Archibald S. Brown**, Wright Field

TUESDAY, NOVEMBER 4

Microwaves

Higher Mode Techniques for Wave Guides, **M. W. Goodhue**, Polytechnic Research and Development Company

Multiplex Transmission Through Wave Guides Using Higher Modes, **R. R. Buss**, **W. A. Hughes**, **H. D. Ross**, and **A. B. Bronwell**, Northwestern University

Microwave Spectroscopy, **D. K. Coles** and **W. E. Good**, Westinghouse Electric Corporation

Noise Reduction in Radar and Communication, **S. Goldman**, Massachusetts Institute of Technology

Joint Session of National Electronics Conference and AIEE, program arranged by AIEE

Computers

Electronic Computers, **J. W. Mauckly** and **J. P. Eckert, Jr.**, Electronic Control Company

Storage of Numbers on Magnetic Tape, **J. A. Coombs**, Engineering Research Associates

Computers for Aeronautical Navigation, **Hugo Schuck**, Minneapolis-Honeywell Regulator Company

Electronic Circuit Analysis

Cathode Tap, Cathode Follower Amplifiers, **Bradford B. Underhill**, Pennsylvania State College

New Developments

Ultrasonic Guidance of the Blind, **Frank H. Slaymaker** and **W. F. Meeker**, Stromberg-Carlson Company

Dynamic Properties of the Infrared Cesium Arc, **J. M. Frank** and **W. S. Huxford**, Northwestern University

Heatless Preservation with Penetrating Electrons from the Capacitron, **W. Huber**, Electronized Chemicals Corporation

Citizen's Radio Service, **R. E. Samuelson**, Hallicrafters Company

General Trends in Foreign Electronic Developments, **A. H. Sullivan, Jr.**, Wright Field

Industrial Electronics

Electronic Half-Tone Engraver, **John Boyajean**, Fairchild Camera and Instrument Corporation

Electronic Servomechanism Testing Machine, **H. W. Katz**, University of Illinois

Sealed Ignitrons for Radio Transmitter Power Supplies, **H. E. Zuvers**, General Electric Company

Single-Phase Controlled-Rectifier and Inverter Circuits, **C. M. Wallis**, University of Missouri

Antennas

High Gain with Discone Antennas, **A. C. Kandoian**, **W. Sichak**, and **R. A. Felsenheld**, Federal Telecommunication Laboratories, Inc.

Slot Antennas, **N. E. Lindenblad**, Radio Corporation of America

Measurement of Aircraft Patterns in Flight, **J. S. Prichard**, Airborne Instruments Laboratory, Inc.

Transmission Frequencies for Line-of-Sight Systems, **L. S. Schwartz**, Naval Research Laboratory

Nucleonics

Mass-Spectrometer-Type Detector, **Robert F. Wall**, Texas Agricultural and Mechanical College

Scintillation Counter, **J. W. Coltman**, Westinghouse Electric Corporation

NOVEMBER 5

Military Applications of Electronics

Guided Missiles, **Walter N. Brown Jr.**, Haller, Raymond and Brown

Telemetry System for Guided Missiles, **L. J. Neelands** and **Walter Hausz**, General Electric Company

Foreign Developments in Infrared, **E. A. Underhill**, Wright Field

Foreign Vacuum Tubes and High-Frequency Techniques, **B. L. Griffing**, Wright Field

Communications

Teleran, A Technical Progress Report, **R. W. K. Smith**, **D. H. Ewing**, and **H. J. Schrader**, Radio Corporation of America

Crystal Saver, **W. R. Hedeman Jr.**, Bendix Radio Corporation

Pulse Count Modulation, **D. D. Grieg** and **S. Metzger**, International Telephone and Telegraph Corporation

Air Traffic Control, **W. D. White**, Airborne Instruments Laboratory, Inc.

Basic Science

Semi-Conductors, **K. Lark-Horovit**, Purdue University

Supersonic Detection of Infrared Modulation, **W. Fry** and **Fry**, University of Illinois

Microwave Scattering, **R. T. Gabler**, Westinghouse Electric Corporation

Industrial Application

High-Frequency Operation of Fluorescent Lamps, **J. H. Campbell** and **B. D. Bedford**, General Electric Company

Magnetostriction Torquemeter, **E. H. Schulz**, Armour Research Foundation

Saturable Core Magnetometer Applications, **W. E. Tolles**, Airborne Instruments Laboratory, Inc.

Television

The Chromoscope, A New Color Television Viewing Tube, **A. B. Bronwell**

Color in Television Cathode-Ray Tubes, **E. B. Fehr**, General Electric Company

A Modern Television Transmitter, **C. D. Kentner**, Radio Corporation of America

Monitoring Equipment for Television Broadcast, **M. Silver**, Federal Telecommunication Laboratories, Inc.

Luminescent Screens For Cathode-Ray Oscillography, **Carl Feldt**, A. B. DuMont Laboratories, Inc.

Electronic Instrumentation II

High Resolving Power Infrared Recording Spectrometer, **R. D. Nelson** and **W. R. Wilson**, Northwestern University

The Phase Meter, **W. O. Vandeven**, General Electric Company

Accurate Measurement of Relative Phase, **R. Glaser**, Massachusetts Institute of Technology

A Null Method for Determination of Impedance in the 100–400-Megacycle Range, **J. F. Byrne**, Airborne Instruments Laboratory, Inc.

Frequency Modulation Broadcast Development

A 50-Kw Frequency Modulation Broadcast Transmitter, **C. J. Starner**, Radio Corporation of America

A Pulse-Counter-Type Frequency Modulation Station

Monitor, **David Packard and Norman B. Schrock,** Hewlett-Packard Company

Transatlantic Frequency Modulation Transmission, **L. B. Arguimbau and J. Granlund, Massachusetts** Institute of Technology

Phase Modulation Circuit, **S. M. Beleskas, Radio** Corporation of America

Electronic Circuit Analysis II

Analysis of Oscillator Frequency **Instability, F. P. Fischer,** University of Connecticut

Transient Behavior in Nonlinear **Systems, Carl S. Roys,** Syracuse University

Calculation of Operating **Characteristics of Electromagnetic Devices, R. M. Soria, American Phenolic** Company, and **T. J. Higgins, Illinois Institute of** Technology

Model Agreements Developed by Bell System and REA

Two model agreements have been developed by the Bell Telephone System and the Rural Electrification Administration with regard to the further extension of telephone service in rural areas. These agreements suggest the general form and substance of contracts which may be executed between Bell Telephone Company and the REA co-operative. They cover the furnishing of telephone service by carrier methods over the co-operative power distribution wires, and the joint use of pole lines so that both the electric and telephone wires may be carried on the same poles in many rural areas.

Power-line carrier telephony makes it possible to transmit telephone conversations over rural electric distribution wires, and in numerous instances is a very practical and economical method of bringing telephone service to farm homes which are distant from existing telephone pole lines but close to electric power lines. By means of specially designed equipment, telephone messages are conveyed along the power line, and leave that line at any selected pole, traveling over a pair of telephone wires to the customer's telephone.

Under the suggested agreement covering power-line carrier, contracts between the individual telephone companies and REA co-operatives will provide that the telephone company supply and own all special equipment required to take the telephone current on and off the power wires. The telephone company also will maintain some of this equipment, but not that part directly associated with the live power wires. The latter part will be maintained by the co-operative at the telephone company's expense. For each pole belonging to the co-operative on which telephone apparatus is placed, the telephone company will pay a rental charge for the right to attach its equipment.

Power-line carrier contracts will be written for a period of five years, but may be terminated or brought up for revision on one year's notice. The "joint use" contracts which cover the placing of both telephone and power wires on the same poles, provide that either the telephone company or the REA co-operative may be the owner of the poles. By paying the rental charges specified, either party may use the other's poles, and if any poles are not suited for the purpose of joint use, the owner will take steps to make them so.

The "joint use" contract will be for a period of 25 years, but the rental charges may be reviewed once in each five years and revised on a mutually acceptable basis. The contract may be concluded at the end of the 25-year contract, or subsequently on three years' notice.

Discussions between the Bell System and the private power companies, looking toward similar agreements, are now under way. The United States Independent Telephone Association has indicated that telephone companies which are not a part of the Bell System also are giving active consideration to contracts of similar type.

Mrs. Edison Dies. Mrs. Mina Edison, widow of inventor Thomas A. Edison, died August 24, 1947, in New York, N. Y. Mrs. Edison, second wife of the inventor, married him in 1886. She was active in the leadership of Chautauqua Institute, founded by her father, and was a prominent prohibitionist and Republican, participating particularly in the Hoover campaigns. Mrs. Edison also was interested in municipal beautification projects, in recreational facilities for children, and in gardening. She remarried in 1935 but was widowed again in 1940, at which time she resumed the name of Edison. In recent years Mrs. Edison was a frequent guest at functions honoring her husband and in February 1947 she attended the Edison centenary dinner held in New York. When the Thomas Alva Edison Foundation was formed in 1946, Mrs. Edison was named honorary chairman. In February 1947 she deeded the Edison winter home in Fort Myers, Fla., to that city for use as a botanical garden, library, and shrine in memory of her husband.

NBS Establishes Commodity Standards Division

Two divisions of the National Bureau of Standards, the Commercial Standards Division and the Simplified Practice Division, have been consolidated into a single unit called the "Commodity Standards Division."

The new unit will continue developing voluntary simplified practice recommendations and commercial standards with industrial and technical groups. In addition, the division will be responsible for co-ordinating new work for the Federal Specifications Board. Edwin W. Ely, former chief of the Simplified Practice Division has been appointed as chief of the new unit, and F. W. Reynolds, former acting chief of Commercial Standards, has been assigned assistant chief.

The simplified practice program, initiated in 1921, is concerned with the elimination of uneconomical variety in a particular line of manufactured products. Commercial standardization, begun in 1927, is directed toward the development of voluntary standards for manufactured products. For both activities, the National Bureau of Standards acts as a centralizing agency only, on request from industrial, commercial, or consumer groups. Compliance with recommendations, which are approved by the groups concerned, is entirely voluntary. The Federal specifications work will be an important function of the new division. Such specifications are vital in the purchase of goods by Federal agencies because the bid system, used by the Government to insure Federal economies in purchasing and to give an equal opportunity to all manufacturers, requires specifications for its operation.

At the present time the National Bureau of Standards is represented on over 100 committees of the American Standards Association and is the managing agency for 17 American Standards Association projects. Similarly, the bureau is represented on 55 of the 63 technical committees of the American Society for Testing Materials with more than 100 memberships, and close relations are maintained with other technical and industrial organizations.

New Traveling Wave Tube Developed at Stanford

Development of a new traveling wave tube that can operate at more than twice the frequency and which has at least twice the band width of the earlier type of traveling wave tube has been announced by Doctor Lester M. Field, electrical engineer on the faculty of the school of engineering of Stanford University, California. This work at Stanford is a continuation by Doctor Field of research begun last year in the Bell Telephone Laboratories by Doctor John R. Pierce and Doctor Field. Their work at that time stemmed from a wartime discovery by a British scientist, R. Kompfner of Oxford University. His idea for the traveling wave tube was perfected by the two American engineers to the point where a tube of unprecedented performance resulted.

The present model of the tube operates at about 10,000 megacycles and is capable of amplifying a band of frequencies approximately 2,500 megacycles wide.

The device is a slim glass pipe containing a long coil of wire, which looks like a spring under tension and is called a helix. Microwaves travel around this coil and are amplified by the stream of electrons shooting past the coil from a cathode. The electrons, moving at about the same speed as the microwaves which are slowed down by the circular route they follow along the coil, give up part of their energy to the microwaves, thus building up the amplitude of the waves.

At present, major emphasis in the research is being placed on theoretical studies which have analyzed four alternative structures as substitutes for the helix coil in the heart of the tube. Mathematically, two of these substitutes appear to be superior to the coil. The technical difficulty that has to be overcome is that the higher the frequencies amplified by a tube, the smaller and more fragile the helix becomes. Doctor Field is striving to produce a fairly large tube, which will not be so delicate that it will be expensive to build, and which will amplify at 25,000 megacycles.

The new tube is capable of amplifying simultaneously 250,000 telephone conversations, or 300 black and white television broadcasts, or 100 television broadcasts in color. It is expected to facilitate commercial expansion of television because of its wide-band amplification characteristics. With further development, it could cut down television costs by reducing the number of amplifying tubes in television sets.

It also provides a feasible method through which long distance telephone lines, with their heavy maintenance problems, can be replaced by a chain of radio relay stations in which the traveling wave tubes will provide ample amplification and room for simultaneous transmission of large volumes of telephone and radio traffic.

Computing Machinery Literature. From the National Bureau of Standards comes word that beginning with the October issue, the quarterly journal, *Mathematical Tables and Other Aids to Computation,* will publish a new feature section called "Automatic Computing Machinery," designed to disseminate information and news on research and development in the field of high-speed automatic calculating machinery. Contributions to this section are invited and should be addressed to Doctor E. W. Cannon, head of the Mathematics Group, Machine Development Laboratory, National Bureau of Standards, Washington 25, D. C. Material should fall under the general headings of bibliography, technical developments, discussions, including correspondence, and news. The journal, edited on behalf of the committee on mathematic tables and other aids to computation, is published quarterly by the National Research Council, and can be obtained from the National Academy of Sciences, 2101 Constitution Avenue, Washington, D. C. Calendar year subscriptions are $4 each and single copies are $1.25.

Western Union Push-Button Telegraph System Announced

A system of push-button telegraphy has been announced by Western Union Telegraph Company, and is in operation at Philadelphia, Pa. The new system will speed traffic in that it will provide for automatic transmission of messages to their destinations.

Each message will be typed only once, at the point of origin. For example, a message sent from a town or a city in the Philadelphia area and addressed to San Francisco will be received at the Philadelphia center by a printer perforator which simultaneously prints the message and punches combinations of holes in a paper tape.

A clerk will read the destination on the tape when the message begins to arrive here and will press a button marked "San Francisco." The pressing of the button will cause the perforated tape to run through an automatic transmitter which will flash the electric signals indicated by the holes in the tape to the San Francisco terminal. There the signals will be received automatically in printed form ready for delivery. Philadelphia's two million dollar system is the largest in a new nation-wide network of Western Union switching centers now being installed to flash telegrams to their destinations with greater speed and efficiency. Using the new system, the present capacity of the switching center will be three times greater than that afforded by previous facilities.

The new push-button center occupies the entire second floor of the Western Union building at Philadelphia, Pa., where a corps of trained workers in a sound-proofed room will handle the large volume of telegrams. The equipment is set up in aisles covering about 16,000 square feet of floor space, and a monitor system guards against mechanical failures.

Professional Engineers Act Passed in California

After several months of effort by interested members of the engineering profession, a Professional Engineers Act was passed during the 1947 session of the California legislature which defines the activities, and permits registration of, electrical, mechanical, chemical, and petroleum engineers.

An earlier attempt by the engineering profession during the late 20's resulted in such widespread differences of opinion that only civil and structural engineers were included in an act which was passed at that time. During the intervening years interested members of the other branches of engineering attempted to promote an act which would be more inclusive.

The new act, passed in June 1947, finally had to be presented as a modification of the original Civil and Structural Engineers Act allowing for registration of the other branches without the comprehensive examinations now required for civil engineers. The act becomes effective in June 1948, and in the meantime, qualified engineers may apply for registration.

The Los Angeles and San Francisco Engineering Councils each appointed legislative committees composed of one member from each of five founder societies, and these two committees co-operated diligently in preparing drafts of required legislation which would permit civil and structural engineers to continue their present standards of registration. Because of the complexity of the San Francisco Engineering Council which includes five associate technical societies along with the five founder societies, and because of the lack of any engineering council in San Diego, it was agreed that the legislative action should be initiated by the Los Angeles Engineering Council which was organized by the five founder societies. Joint action then was obtained throughout the state by co-operation of the engineering societies.

Much of the success for the passage of the act is due to the untiring efforts of W. L. Chadwick (M '38) civil and electrical engineer, and president of the Los Angeles Engineering Council. Other electrical engineers who assisted greatly in the promotion and passage of the act include Doctor Royal W. Sorensen (F '19) AIEE past president (1940–41), and D. I. Cone (F '42) vice-president of District 8 (Pacific).

In California the membership of the five founder societies totals about

AIEE	2,500
American Society of Mechanical Engineers	2,500
American Institute of Chemical Engineers	500
American Society of Civil Engineers	4,000
American Institute of Mining and Metallurgical Engineers	2,500
Total	12,000

At present about half of the ASCE membership and an additional 2,500 civil or structural engineers are registered under the original act. A study of the future indicates that an additional 4,000 engineers may register under provisions of the new act. Arrangements are included to register without examination those registered engineers from other states having professional acts with equivalent standards. Fees for registration include $15 application fee, $10 for initial certificate, and $6 for annual renewal.

The act is to be administered by a board, appointed by the governor, of seven registered engineers, who will retire individually and on successive years. Arrangements are included in the act to insure that the board always will contain at least one member from each of the five major branches of the engineering profession.

Though it is agreed that the present form of the new act leaves much to be desired, it is welcomed as another step forward in the unification of engineers within the state. Plans are being made for a committee which will develop and protect the act over the coming years.

Those interested may obtain copies of

the act by writing the State Printing Office in Sacramento and asking for a copy of Assembly Bill 1930 of the 1947 legislature.

Carrier Communication System Installed in Northwest

The first modern single-sideband suppressed-carrier power-line communication system recently was installed for use between Portland, Oreg., and Pasco, Wash., for the Pacific Power and Light Company by the Westinghouse Electric Corporation.

Transmitting on a nominal frequency of 91.4 kc, the equipment was tested between Pasco and Spokane, a distance of 149 miles. Under adverse conditions, including a measured carrier channel attenuation of about 60 decibels and an interfering signal of several volts that was less than 10 kc from a mid-sideband frequency, clear understandable voice communication was maintained throughout the test.

While the equipment installed at the Pacific Power and Light Company is a complete single-sideband power-line carrier-communication system, certain components are designed and put together in the form of a converter unit that will convert common amplitude modulation carrier systems of proper design into single sideband systems.

Welding Patents Classified. A classification system for more than 11,000 welding patents now in the Davis Welding Library at Ohio State University, Columbus, has been established. Doctor W. H. Simon of the University of Toronto, Toronto, Ontario, Canada, was in charge of the project which will enable industries, students, and research workers to obtain information more readily on all patents granted in their specific lines. Cost of the work was paid from the A. F. Davis welding engineering scholarship and library fund. The library includes a large collection of patents relating to the welding processes and their industrial applications.

Sparkproof Cable. A new cable that will not spark when short-circuited has been developed jointly by engineers of the United States Rubber Company and Leonard Wilson of Kenilworth Mines of Utah to aid in the prevention of coal mine explosions. The new feature of the new cable is a fine strand of copper wire over the insulation of the positive conductor. Should damage to the insulation occur, the fine wire catches incipient current leakage before an arc can occur and carries it through the coil of a sensitive circuit breaker to ground. It is expected to eliminate a common source of danger in coal mines, for this type of cable is used to carry power to heavy equipment employed in digging and transporting coal. The cable, continually trailing on the ground, is in constant danger of being damaged.

C. M. Osterheld Dies. Clark M. Osterheld, vice-president and general manager of the Clark Water Heater Division of the McGraw Electric Company, Chicago, Ill., died in Madison, Wis., July 6, 1947. He was widely known and respected in the electrical industry as a pioneer, inventor, and executive in the electric water heating field. Among some of his best known improvements are a wide-area low-temperature heating element and the use of magnesium rods for protection against tank corrosion.

J. K. Northrop Wins Aviation Honor

The Spirit of St. Louis Medal, highest aviation honor of The American Society of Mechanical Engineers, has been awarded this year to John K. Northrop, president of Northrop Aircraft, Inc., Hawthorne, Calif., for his development of the "flying wing" and other contributions to aeronautical science.

The medal was conferred at a banquet during the annual fall meeting of the ASME in Salt Lake City, Utah, September 1–4, 1947. The citation accompanying the medal read: "To John Knudsen Northrup for his originality and vision in the engineering of military and commercial airplanes, and particularly for his development of a successful flying wing."

The medal, awarded every third year "for meritorious service in the advancement of aeronautics," commemorates the trans-Atlantic flight of Charles A. Lindbergh made in 1927, in his airplane, "The Spirit of St. Louis." The aircraft is now in the Smithsonian Institution in Washington, D. C.

OTHER SOCIETIES

ASCE Annual Meeting Held in Minnesota

The annual meeting of the American Society of Civil Engineers was held July 16–18, 1947, in Duluth, Minn. Construction, highways, waterways, power, and other civil engineering subjects of particular interest to the Midwest were featured at the ten technical sessions of the meeting.

Various aspects of the Taft-Hartley Labor Bill were covered by E. M. Hastings, national president of the society, who indicated that now, for the first time, a definition is provided for professional employees, and that provision is made for a differentiation between such employees and nonprofessional employees.

Future Meetings of Other Societies

American Institute of Chemical Engineers. Annual meeting, November 9–12, 1947, Detroit, Mich.

American Institute of Mining and Metallurgical Engineers. Annual meeting, February 15–19, 1948, New York, N. Y.

American Society of Civil Engineers. Fall meeting, October 15–17, 1947, Jacksonville, Fla.

American Society for Metals. Meeting jointly with **National Metal Congress.** October 20–24, 1947, Chicago, Ill.

American Society for Testing Materials. Spring meeting and committee week, March 1–5, 1948. Washington, D. C.

American Society of Tool Engineers. Semiannual meeting, October 30–November 1, 1947, Boston, Mass.

American Standards Association. Annual meeting, October 21–23, 1947, New York, N. Y.

American Transit Association. Annual convention, October 8–10, 1947, Atlantic City, N. J.

American Welding Society. Annual meeting, October 20–24, 1947, Chicago, Ill.

Canadian Institute of Radio Engineers. Convention, April 30–May 1, 1948, Toronto, Ontario, Canada.

CIGRE (International Conference on Large Electric High-Tension Systems). Biennial meeting, June 24–July 3, 1948, Paris, France.

Engineers' Council for Professional Development. Annual meeting, October 24–25, 1947, Montreal, Quebec, Canada.

Exposition of Chemical Industries. 21st annual exposition, December 1–5, 1947, New York, N. Y.

Fluorescent Lighting Association. Cold cathode fluorescent lighting exhibit, October 7–9, 1947, New York, N. Y.

Institute of Radio Engineers. Fall meeting held jointly with the **Radio Manufacturers Association Engineering Department,** November 17–19, 1947, Rochester, N. Y.

International Lighting Exposition and Conference. November 3–7, 1947, Chicago, Ill. Sponsored by National Electrical Manufacturers Association.

National Association of Manufacturers. 52d Annual Congress of American Industry, December 3–5, 1947, New York, N. Y.

National Electrical Manufacturers Association. October 27–31, 1947, Atlantic City, N. J.; winter convention, March 14–18, 1948, Chicago, Ill.

National Electronics Conference. November 3–5, 1947, Chicago, Ill.

National Safety Congress and Exposition. 35th annual meeting, October 6–10, 1947, Chicago, Ill.

Pacific Chemical Exposition and Pacific Industrial Conferences. October 21–28, 1947, San Francisco, Calif.

Pennsylvania Electric Association. Prime movers committee fall meeting, October 23–24, 1947, Philadelphia, Pa. Electric equipment committee fall meeting, October 9–10, 1947, Altoona, Pa.

Refrigeration Equipment Manufacturers Association. All-Industry Refrigerating and Air-Conditioning Exposition. January 26–29, 1948, Cleveland, Ohio.

Society of Automotive Engineers. National aeronautic meeting, October 2–4, 1947, Los Angeles, Calif.

Substitution of a national water policy for present "piecemeal development of water programs," to eliminate jurisdictional conflicts and confusion and to help avert recurrences of floods such as those which recently plagued the Midwest, was advocated by W. W. Horner, St. Louis, Mo., a past president of the ASCE. In discussing the work of a temporary committee authorized by the Engineers Joint Council to explore procedures necessary for the establishment of a national water policy, Mr. Horner pointed out that its work will constitute a contribution of the engineering profession toward the desirable goal of establishing a policy to co-ordinate present disjointed efforts and to effectuate treatment of water as a national resource to be conserved and utilized in the best and most economical interests of all the people.

E. M. Hastings, president of the ASCE, in his opening address, urged that engineers emerge from the narrow confines of a purely technical life and of purely technical thinking, and that they assume leadership in national and world affairs by providing the nonpolitical, unbiased, factual, and analytical thinking of which they are capable.

A discussion of the social labor laws of some Latin American countries was presented by J. J. Collins, New York, N. Y., vice-president and director of foreign work, Raymond Concrete Pile Company. Mr. Collins pointed out that a local workman in the course of the year received about 100 per cent increase over the basic wage of extras. The extras referred to are the following. First, the workman is paid travel time to and from his home or an assembly plant near his home. In addition, transportation is provided. He receives 15 working days vacation per year. He is paid seven days per week, providing he has worked all of the working days of the week. If he misses one working day without excuse then he forfeits his day-of-rest pay. In addition, he is allowed a percentage of the company's profits, an amount not to exceed 16²/₃ per cent of his total income per year paid. He also is taken care of for certain periods if he has an illness, and receives an allowance if living quarters are not available for him. In general, according to Mr. Collins, the social labor laws of some Latin American countries are far beyond the United States.

Robert L. Fitzgerald, vice-president and general manager, Duluth Steam Corporation, Duluth, Minn., in a luncheon address stated that Russia is processing from 50 to 60 million tons of bog peat into gas and power to serve industrial needs. Though detailed information on the Russian operation is far from complete, Mr. Fitzgerald asserted that Russia had eliminated the inherently high peat transportation costs by converting the peat into electric power and fuel gas at the site of the bog and transmitting the end products to the points of consumption. Man-hours have been reduced from 75 to 80 per cent by introducing hydraulic and mechanical material handling method. Power stations of up to 200,000 kw capacity are being operated on peat fuel. The Russians consider their peat bogs as large reservoirs of a wide variety of chemical products. They are keeping a staff of 300 research scientists busy studying methods for recovering the chemicals on a commercial scale.

At the society's board of directors meeting, Richard E. Dougherty, vice-president of the New York Central Railroad, was nominated as the 1948 president of the ASCE.

National Conference on Industrial Hydraulics Scheduled

The third annual meeting of the National Conference on Industrial Hydraulics (formerly the Hydraulic Machinery Conference) will be held on October 16–17, 1947, at the Hotel Continental in Chicago, Ill.

This year's conference is being sponsored by Armour Research Foundation and the graduate school of Illinois Institute of Technology in co-operation with the Western Society of Engineers and the Chicago sections of the Society of Automotive Engineers, American Society of Civil Engineers, and the American Society of Mechanical Engineers.

The program will include some 12 papers on such subjects as fundamentals of hydraulic governor operation, hydraulic circuits of industrial process controls, hydrokinetic transmission, torque converters, recent developments in hydraulic transmissions, variable speed hydraulic power transmission, development of hydraulic seals, and problems of engineering research.

Western Engineers' New Secretary. Donald V. Steger, formerly director of industrial relations of the John B. Stetson Company, Philadelphia, Pa., has been elected executive secretary of the Western Society of Engineers. He succeeds Leigh S. Keith, who has been secretary of the society since 1935.

Conference to Be Held on X-Ray and Electron Diffraction

The 1947 meeting of the Pittsburgh Conference on X-ray and Electron Diffraction will be held at the Mellon Institute of Industrial Research, Pittsburgh, Pa., November 7–8, 1947.

A program for the meeting now is being prepared. Local interests indicate that one session could be devoted to studies on insterstitial compounds, and that another session might be devoted to X-ray and diffraction studies at high temperatures. The two remaining sessions will consist of contributed papers concerning the theory and practice of X-ray and electron diffraction. Papers now are being submitted, and the official program should be completed soon.

Relay Association Organized. "NARM," the National Association of Relay Manufacturers, was organized formally in Chicago, Ill., on May 17, 1947, when representatives of leading relay manufacturers from all parts of the United States drew up a charter of aims. Ralph T. Brengle, Potter and Brumfield Sales Company, Chicago, Ill., was elected the first president. Standardization of relay ratings is one of the principal aims of the new organization. The group also is expected to take steps toward the solution of other mutual problems such as material specification, general characteristics, classifications, government and underwriters' specifications, and more effective metallurgical research for improvement in performance and durability of products. Standardization of general nomenclature and terminology in cataloging throughout the field also is contemplated.

Tool Engineers to Meet in Boston

Various aspects of tooling will be discussed in the 3-day semiannual convention of the American Society of Tool Engineers, which is to be held October 30–November 1, 1947, in Boston, Mass. The theme of the meeting is "more efficient machine tools will lead to a sounder economy."

The technical sessions will include discussions of such subjects as abrasives, the importance of welding to tool engineers, material handling, bearing applications, the professional development of tool engineers, and tooling for watches and clocks.

Inspection tours of plants in the Boston area are included in the program of the meeting. The engineering laboratories of the Massachusetts Institute of Technology also will be open to those attending the meeting.

Chicago to Be Site of AWS Annual Meeting

The tentative program for the 28th annual meeting of the American Welding Society has been announced. The meeting is to be held at the Hotel Sherman, Chicago, Ill., October 19–24, 1947, during the National Metal Exposition.

Highlighting the meeting will be President L. W. Delhi's reception on Sunday evening, October 19; the Adams lecture by G. S. Mikhalapov, manager, apparatus research, Air Reduction Sales Company, and the awards of prizes and medals on Monday evening, October 20; the university research conference, Tuesday evening, October 21; the section conference, Wednesday evening, October 22; and the annual banquet on Thursday evening, October 23.

In addition to the technical sessions, welding and cutting exhibits at the National Metal Exposition also are planned. This exposition has been extended to run a full week starting Saturday, October 18, 1947.

EDUCATION • • •

New Dean at Stevens. Doctor Waldo Shumway, scientist, professor, and former assistant dean of the college of liberal arts and sciences of the University of Illinois, has been appointed dean of Stevens Institute of Technology. He will fill the position held by Dean Frederic E. Camp who is being promoted to the position of assistant to the president without portfolio.

Texas College Adds Electrical Courses. The Texas College of Mines, El Paso, now is granting degrees in electrical and civil engineering. Courses have been added to the curriculum to take care of students majoring in electrical and civil engineering. Third year students enrolled in the fall semester will be able to complete work for either degree by June 1949. Senior courses in both divisions will not be added to the curriculum until the fall of 1948.

RESEARCH • • • • •

RCA Fellowships Granted for 1947–1948

The Radio Corporation of America Fellowship Board of the National Research Council has announced the first series of awards to five young scientists. These fellowships for the academic year 1947–1948 provide for advanced graduate study and research in electronics. The successful candidates for these awards are

Arnold S. Epstein, bachelor of science in electrical engineering, Lehigh University, Bethlehem, Pa., for continuation of graduate study at the University of Pennsylvania, Philadelphia, with special reference to selenium and other rectifiers as variable capacitors.

Willis W. Harman, bachelor of science in electrical engineering, University of Washington, Seattle, for continuation of graduate study at Stanford University, Stanford University, Calif., with special reference to the use of microwaves in certain cavity oscillators.

Arnold R. Moore, bachelor of science in chemistry, Polytechnic Institute of Brooklyn, Brooklyn, N. Y., for continuation of graduate study at Cornell University, Ithaca, N. Y., with special reference to electronic properties of semiconductors.

Sol Raboy, bachelor of arts in physics, Brooklyn College, Brooklyn, N. Y., for continuation of graduate study at Carnegie Institute of Technology, Pittsburgh, Pa., with special reference to the properties of semiconductors and their use as crystal counters.

H. Gunther Rudenberg, bachelor of science and master of arts in physics, Harvard University, Cambridge, Mass., for continuation of graduate study at Harvard University with special reference to operation and design of wide-band pulse amplifiers.

These fellowships have been made possible by a grant to the National Research Council from the Radio Corporation of America, Inc., for the purpose of increasing the number of trained scientific personnel and for the advancement of electronics and closely related fields.

Applications for the next series of awards for the academic year 1948–49 should be filed before February 1, 1948. Stipends will be from $1,600 to $2,100 a year, and an added amount, not to exceed $600, may be provided annually to the institutions to which the fellow is assigned for tuition or necessary equipment.

Further information concerning the fellowships and application blanks may be secured from the Secretary of the RCA Fellowship Board, National Research Council, 2101 Constitution Avenue, Washington 25, D. C.

Conference to be Held on Administration of Research

A conference on administration of research will be held at the Pennsylvania State College on October 6–7, 1947. The main purpose of the conference is to provide free discussion on the organization, administration, and operation of research laboratories.

Discussion will be led by Professor Philip M. Morse, Brookhaven National Laboratories; and Doctor Jesse E. Hobson (M '41) Armour Research Foundation. The following men are listed as the principal speakers:

Maurice Holland, New York, consultant

Doctor R. L. Jones (F '31) Bell Telephone Laboratories

Doctor G. H. Young, Mellon Institute of Industrial Research

Doctor Dwight E. Gray, Applied Physics Laboratory

Doctor L. Warrington Chubb (F '21) Westinghouse Electric Corporation

Doctor Edward U. Condon (M '44) National Bureau of Standards

The Honorable James H. Duff, Governor, Commonwealth of Pennsylvania

Commodore Henry A. Schade, director, Naval Research Laboratory

Doctor Paul D. Foote and Doctor Blaine B. Wescott, Gulf Research Laboratories

Doctor Albert W. Hull, General Electric Company

LETTERS TO THE EDITOR

INSTITUTE members and subscribers are invited to contribute to these columns expressions of opinion dealing with published articles, technical papers, or other subjects of general professional interest. While endeavoring to publish as many letters as possible, Electrical Engineering reserves the right to publish them in whole or in part or to reject them entirely. Statements in letters are expressly understood to be made by the writers. Publication here in no wise constitutes endorsement or recognition by the AIEE. All letters submitted for publication should be typewritten, double-spaced, not carbon copies. Any illustrations should be submitted in duplicate, one copy an inked drawing without lettering, the other lettered. Captions should be supplied for all illustrations.

Electrostatic Ills

To the Editor:

This letter proposes that Robin Beach's paper "Electrostatic Ills and Cures of Aircraft" (*EE Apr '47, pp 325–34; EE May '47, pp 453–62*) does not measure up to the unadulterated standards of *ELECTRICAL ENGINEERING* articles.

During the past war, the writer was associated intimately with the joint Army-Navy extensive research on the serious flight hazard, precipitation static interference, and accordingly feels that he is reasonably qualified to comment on the subject article.

In spite of his limited experience on this problem and his quite inadequate flight facilities, Mr. Beach purports in no unassuming manner—which includes liberal dosages of ostentatious technical "gilding of the lily"—to have dispatched with finality the *working* results of this significant war research project. In support of these remarks, a few typical examples of his inaccuracies are selected and commented on.

Part I of the article contains a good technical review of the precipitation static interference problem as developed by a number of researchers. But, his statement that "The United States Armed Forces have reported that some 25 per cent of the airplane casualties in the Army and Navy during the war, at home and abroad, resulted directly from the obliteration of radio communications and the erratic behavior of certain radio flight instruments by static interference" is fearsome garbling of the military report that 25 per cent of the aircraft losses by one training activity in the northwest part of this country were caused by precipitation static interference.

An array of exploded parts of an aircraft trailing wire antenna reel, Figure 1, appears in this article and by innuendo the destruction is related mysteriously to precipitation static. To dispose of this hobgoblin, it should be pointed out that the explosion of this aircraft component obviously resulted from a lightning stroke to the extended trailing antenna and was conducted into the fuselage through the fiber fairlead. As the wire fused at the external end of the fairlead, an arc was pulled into this typical expulsion tube and the resulting tremendous gas pressure did the damage shown. This has been a not uncommon flight experience and corrective principles have been worked out. In any event, it is a lightning hazard problem, bearing very remote relationship to the discussions of the article, and certainly would not be prevented by the installation of static dischargers.

The article explains: ". . . electrostatic dissipators must be sufficiently effective dischargers to maintain the potential of the airplane well below the threshold of ionization of all burrs, antenna insulators, insulated members, and other parts of critical sharpness." But no specific mention is made of the antenna wire which is in the order of 25 mils in radius and on large aircraft extends in some sections five feet or more above the top of the fuselage. This particular fact happens to be the crux of the subject problem, and yet in the subject article it is avoided or ignored completely so far as technical discussion is concerned. Ordinarily, it would be unnecessary to point out that the ionization threshold of a "burr" on the surface of an airplane is lower than, in fact not even of the same order of magnitude as, that of the aforementioned antenna wire.

The author's opinions liberally offered to support his condemnation of polyethylene-insulated antenna wire are refuted by the services' experience for the past three or four years. Puncture of the insulation *may* occur only when the aircraft is flown into thunderstorm fields of magnitude approaching that required to produce a lightning stroke, but not from autogenous charging. In the event of puncture, the resulting precipitation static interference is no worse than from the same wire uninsulated. Furthermore, the pilot still has several other sound antennas to switch to—an important operational advantage.

Part II of the article has the unmistakable timbre of an advertising section. Comments will be confined to pointing out that the author makes only an opinionated extrapolation from his maximum test gap spacing of 12 centimeters, to the aircraft in flight where the "metallic bristle ionizers" are mounted on the huge shielding plane of the aircraft structure as one electrode of the "gap" and with *space* as the other! A number of researchers in the past have experimented with surgically fine needles and bristles, but these had been discarded for obvious practical reasons. The author-disparaged dry wick was evolved from relatively extensive Army-Navy research and flight experience as the most practical discharger, despite Mr. Beach's opinions to the contrary.

In conclusion, it should be stressed that with the present state of the art, the discharger alone is not represented by the services as the answer to the elimination of precipitation static interference. Flight research in all types of weather has shown that commonly encountered charging rates (data available to Mr. Beach or anyone interested in reading the technical papers that have been published) are far in excess of the discharging abilities of Mr. Beach's or any other known discharging device. Accordingly, it must be considered only a component of the antiprecipitation static antenna system. This complete "system," including insulated wire antennas when properly installed, has turned in a service record showing at least an 80 per cent reduction in the incidence of precipitation static interference in aircraft.

J. H. WILLOX (A '39)
Joslyn Manufacturing and Supply Company, Chicago, Ill.)

To the Editor:

Mr. Willox raises some interesting although quite elementary points for discussion. A profusion of literature on ionization phenomena and properties of dielectrics answers some of the points of discussion and specific experience in the subject settles other differences of opinion.

Although in Mr. Willox's opinion the antenna wire is the "crux of the subject problem," this is true only insofar as radio interference from electrostatically unprotected aircraft is concerned. With really effective static dischargers on an airplane, the antenna when properly installed presents no electrostatic problem. This comes about by virtue of the fact that, when only the glow stage of corona is present on slender wire-point dischargers, the corona current causes no shock excitation of radio equipment coupled to the grounded antenna. However, when the *burst-pulse corona* discharges start, at higher field gradients, highly attenuated radiation disturbances may be detected through air as far as ten feet away or, by conduction, lesser attenuated ground disturbances may be transmitted further.

Obviously the use of polyethylene insulation on an antenna does not inhibit the wire from receiving interference signals, if they exist, either from radiation or from ground conduction. The sole purpose of such insulation is to eliminate the occurrence of noisy ionization from the wire itself when it acquires by conduction a high potential from the charged airplane as the result of inadequate dissipation of the static electricity. Here the noise impulses are generated on the antenna wire itself and thus they directly shock-excite the associated radio receivers. Experience commonly has demonstrated, much to the grief of maintenance personnel of the Army and Navy air forces and commercial airlines, that the polyethylene does not long perform even this desirable function of inhibiting ionization from the antenna wire.

Wide temperature cycles cause the polyethylene to loosen at spots from the small diameter antenna wires, causing voids which are notorious offenders—above the critical ionizing gradients—in permitting powerfully destructive electrical and chemical agencies to burn and develop holes through the insulation. These destructive conditions have been noted even in the thick mica-folium insulation of power generators and other high-voltage equipment. The presence of over-voltages, of course, accelerates these processes of deterioration of the insulation, although on airplanes the ineffectual wick dischargers permit destructive ionizing potentials to occur on the antenna even when only relatively low precipitation-static exists.

Under conditions of moderately high potential on an airplane, a bare antenna wire starts ionizing from the many weathered points along its length, thereby lowering the potential of the airplane to a considerable degree—somewhat like the early forms of trailing-wire dischargers. With the insulated antenna punctured at one spot only, the total current discharged from the wire under the same potential as the foregoing obviously is limited to a small fraction of that from the bare wire but the discharge from the puncture-spot may be noisy enough to obliterate all radio communication. Now, unlike the former instance, the intense noise may persist long because of insufficient discharge to lower appreciably the high potential on the airplane. With really effective static dischargers, the potential of airplanes is maintained so far below the ionizing threshold of antenna wires that the use of polyethylene insulation on antenna wires is quite unnecessary. In the light of competent experience with ionization phenomena, as recorded in the literature, it is very difficult to understand Mr. Willox's belief that polyethylene insulation will puncture only from electric field strengths of the "magnitude approaching that required to produce a lightning stroke."

Regarding the "extensive Army and Navy research and flight experience" in developing the wick, Mr. Willox's attention is invited to the obvious fact that an extensive and costly research project, *per se*, offers no assurance of successful attainments. In fact, the reverse is true too often, as is exemplified by the fiasco suffered in the development of the colloidal-silver-treated textile wick as an alleged dissipator of static electricity from airplanes.

In the development of this wick, the electrical resistance from end to end was critically designed and gauged to a value of one or two megohms by controlling the amount of the conductive silver impregnation. However, experiences of electrostatic specialists in industry relative to the resistance instability of conductive impregnants, such as metallic salts, chemicals, or graphitic compounds in a dielectric, should have warned Mr. Willox and his coworkers on this static project of the fallacy of such a device as an effective or dependable electrostatic discharger.

Specifically, several hundred serviced wicks of the American Airlines which had been in use on airplanes for varying periods of time, some full length and some having been end-trimmed once or twice, picked entirely at random from a reserve supply presumably in good order and ready for installation on airplanes, were tested individually to determine their electrical resistance. In these tests I found that 95 per cent of these wicks had resistance values exceeding by as much as several hundred to well over 2,000 times the 1-megohm resistance value required by the governing Army-Navy specification,—resistance values so high as to inhibit any appreciable dissipation of static charges through the wicks. These resistance-aging characteristics of used wicks since have been confirmed by Trans World Airlines (TWA). Even from a reserve supply of 215 brand new wicks purchased by Pan American Airways, measurements showed only 30 of them to possess resistance values of 10 megohms or less. The resistances of the remaining 185 new wicks ranged from 50 to over 1,000 times higher than the 1-megohm value specified by the Army and Navy. Hence, the wick not only is useless in its presumptive role as a safety feature on aircraft, but in itself constitutes a hazard because of the induced false sense of security from acknowledged electrostatic hazards.

The phenomenon of increased electrical resistance of a material employing a conductive impregnation of dielectrics is the well-known condition of resistance-aging which results from repeated flexure. Flexure creates discontinuities of conduction through the composition of the material and the resulting increase in electrical resistance commonly is found to be higher by many orders of magnitude. Startling as it may be, I recently have been informed by authoritative sources that the personnel on the Army-Navy static project were and, perhaps, still are unaware of this important resistance-aging phenomenon which was so critically basic to the development of the work. This naturally interjects a question of serious doubt as to the value of the results of the entire Army-Navy electrostatic research project.

The many other inferior and impractical elements incorporated into the design of the wick discharger brings to mind the story of the general who lost his fort to the enemy during the heat of battle. Later, when he was taken to task for his derelictions in a senatorial investigation, the general proposed 100 reasons for his losing the fort, stating as his first reason that he ran out of ammunition. The senators, not interested in the 90 and 9 minor reasons, told him to stop right there while they deliberated upon appropriate punitive recommendations for his shortcomings of preparation and supervision.

Also, it should be stated that, when terminated as a presumably completed subject, the Army-Navy project had only arrived at the threshold of the more serious aspects of electrostatic hazards on airplanes, which apparently not even were recognized by Mr. Willox and his co-workers. Among these problems may be mentioned the following typical examples:

1. High-frequency oscillations generated on propeller blades, where the density of airplane electric charge is highest.

2. The coupled systems of electric oscillations within the mechanical circuits of the engine banks—through the thrust bearings, crank shafts, connecting rods, and piston heads—all with aperiodic discontinuities of resistance at intervening oil films of the bearings.

3. Spark blemishes and arc craters of bearings from spark-overs through oil films.

4. Potential explosion possibilities within crankcases by the occasion of sparks occurring in the space normally pervaded by explosive mixtures of gasoline vapor and air.

5. The "cracking" of lubricating oil by sparks which, in causing the formation of acids, produces accelerated deterioration of bearings.

May I take this occasion of expressing my appreciation to Mr. Willox for the opportunity afforded by his letter to call attention to the utter failure of the wick as an airplane antistatic device and to explain again the fallacies underlying the use of polyethylene-insulated antennas, as well as to enumerate the other important phases of the electrostatic hazards on airplanes which apparently were not recognized or considered by the Army-Navy static research personnel. In view of these sins of commission and omission, the last sentence of Mr. Willox's letter makes a better "swan song" than the "benediction" he intended.

ROBIN BEACH (F '35)

(Robin Beach Engineers Associated, Brooklyn, N. Y.)

Labor Legislation

To the Editor:

The recent message from AIEE President (now Past President) J. E. Housley (*EE, Apr '47, p 390*), which reported on the legislative proposals now before the congress of the United States, focused attention on two problems of fundamental importance to all engineers—unionization and professionalism. We, many of us, are apt to think of legislation as in itself a panacea for existing ills, and too often the legislative enactment is accepted as a solution to problems which go to the very core of social relations. Yet, laws of themselves can correct nothing. They are merely tools with which to work. So it is with the proposed legislation dealing with the relation between unions and engineers.

The problems underlying the professional organization of engineers are numerous and intricately related. Professional organization, however, is neither a competitor nor the antithesis of unionization. While it is probable that unions and professions stemmed from common origins, they are no longer on the same level. On the other hand, the mere existence of professional attributes never precludes unionization, although each has a different place in modern society. The need for unionization of any group still finds its roots in the complexities of modern industrial development and the continuing and expanding trend toward corporate organization. The corporate concept probably is essential to industrialization. Whatever one's social views may be, it is too late to reject the corporation. Nevertheless, it must be accepted as a fact that the corporation begets unionization regardless of the nature of the work performed by its employees. It also must be recognized that corporate bigness also creates union bigness.

Unionization is too often a local problem stemming from relationships between employer and employees which have brought about working conditions and standards that can be solved only through organization of the employees into an effective bargaining group. More often than not, the engineers working under such circumstances have sustained the same grievances. Their professional status offers no solution and the question of unionization and the determination of the bargaining group is therefore essentially local. It should be so treated and the choice of union and bargaining group should be left in the hands of the employees involved.

Any program directed toward alteration of the employee benefits accruing to the engineer under existing legislation should carry with it a professional engineering bill of rights. At the same time, it must be recognized that a profession can not be created by legislative fiat. The profession must exist in fact; the legislative function is to protect it and give it status. The late Justice Cordoza once said:

> In these moments of disquietude, I figure to myself the peace of mind that must come, let us say, to the designer of a mighty bridge. The finished product of his work is there before his eyes with all the beauty and simplicity and inevitableness of truth.
>
> He is not harrowed by misgivings whether the towers and piers and cables will stand the stress and strain. His business is to know. If his bridge were to fall, he would go down in disgrace and ruin.

In those magnificent words are found the basic concepts of the engineering profession, and no legislature can add one iota to the professional stature of the engineer. The legislative contribution must be directed toward the advancement and protection of his position in society.

Legislation should create the basic framework within which the engineering profession can function as a self-governing body. Such an enactment should encompass the following principles:

1. Uniform rules for the admission of members to the practice of engineering.

2. Abolish the common practice of drafting room and shop apprenticeship upon graduation.

3. Establish educational standards directed toward complete basic training.

4. Prohibit any person from performing engineering work of any nature whatsoever without a professional license.

5. Prohibit any employer from hiring any person to perform engineering work of any nature whatsoever unless such person is a registered professional engineer.

6. Prohibit corporations from performing engineering work of any nature whatsoever for any person in connection with the sale of any equipment, device, product, or services.

7. Prohibit engineers from incorporating to perform engineering work.

8. Protect the right of authorship by providing that all correspondence, drawings, designs, articles, literature, and so forth, dealing in any manner with engineering matters of any nature whatsoever, must bear the signature of the engineer originating such work.

9. Provide for compensation commensurate with the professional level of the work performed.

10. Provide for the free exchange of scientific, technical, and engineering information without jeopardizing patent and other private rights.

If any of these principles is to be given a preferred position, it should be the adoption of uniform rules for the admission of engineers. The engineering student should be aware of the standards which he must meet to practice his chosen profession upon graduation and these standards should not be limited to technical fields. He should know that his right to engage in such practice will be determined immediately upon completion of his education by suitable comprehensive examination of his character and fitness, and that after his admission he will be required to measure up to the standards of his profession. To do this requires the employer to recognize the professional dignity of the engineer and end the despicable practice of securing high class engineering work from low paid apprentices, in the drafting room or student courses.

The Congress can do much toward the advancement of the engineering profession by making such standards applicable in the Federal service and by applying them to all employers and engineers engaged in interstate commerce. This is not legislation for the promotion of a vested interest or pressure group, but rather a recognition of the public interest in the advancement of the most constructive professional unit of our modern complex society, for wherever you find civilization progressing toward a higher standard of living, there you will find the engineer also.

WILLIAM HAMILTON TREADWAY (M '42)
(Consulting engineer, Aston, Md.)

NEW BOOKS . . .

"Theory and Application of Radio-Frequency Heating." In addition to accurate and detailed derivation of the basic equations for radio-frequency heating, this book contains data and instructions to aid the design engineer and the applications engineer. The scope of the book is remarkable and makes it a virtual textbook of induction heating, radio-frequency heating, drying, sterilization, plastic welding, wood glueing, and induction heating. By George H. Brown (M '41), Cyril N. Hoyler, Rudolph A. Bierwirth. D. Van Nostrand Company, Inc., New York, N. Y., 1947, 370 pages, illustrated, cloth-bound, 6 by $9^{1}/_{4}$ inches, $6.

"Television" (volumes 3 and 4). This collection of outstanding technical literature on the developments in television is divided into two volumes. Volume 3 covers the period 1938–41 and contains summaries of the articles appearing in volumes 1 and 2. Volume 4 reviews the field from 1942 to 1946. Both volumes are complete in the scope of the articles which includes such classifications as pickup, transmission, reception, color television, and military television. Edited by Alfred N. Goldsmith (F '20), Arthur F. Van Dyck, Robert S. Burnap (M '29), Edward T. Dickey, George M. K. Baker. *RCA Review*, Princeton, N. J., 1946 and 1947, 486 and 510 pages, cloth-bound, 6 by 9 inches, $2.50 per volume, $1.50 per paper-bound volume.

"Power Factor in Your Plant." Joe Edwards, a chief electrician, joined the ranks of the power-factor-conscious because of a sad experience with additional welder loads. However, he found it difficult to convince his men or to find books about the subject which they could understand. W. C. King has solved his problem with a comprehensive but simple discussion of the problems of power-factor control. Although written as a practical guide to the maintenance man, the book well can serve other uses for engineers. By W. C. King. Cornell-Dubilier Electric Corporation, South Plainfield, N. J., 1946, 214 pages, illustrated, 6 by $9^{1}/_{4}$ inches, $3.

"The Rome Cable Manual of Technical Information." The Rome Cable Corporation includes: wire and cable technical tables, wire and cable engineering calculation and data, audio- and radio-frequency wire and cable data, National Electrical Code data, properties of materials, general technical information, conversion tables, and mathematical tables. The manual is a concise and compact reference for problems related to wire and cable application. Rome Cable Corporation, Rome, N. Y., 1947, 263 pages, cloth-bound, 5 by $7^{1}/_{2}$ inches, $2.50.

"Calculating Machines—Recent and Prospective Developments." The inaugural lecture by D. R. Hartree, as Plummer professor of mathematical physics at the University of Cambridge, England, reviews the progress of calculating machines from the mathematical calculations necessary for antiaircraft gunnery in World War I, under the direction of Sir Ralph Fowler, whom Hartree succeeded to the Plummer chair of mathematical physics. The two classes of calculating devices, namely the analogue and the digital machines, are described. Main topic of the book is the electronic numerical integrator and calculator (ENIAC) at the University of Pennsylvania, Philadelphia. This machine is of particular interest because it utilizes electronic circuits as the actual computing element instead of mechanical devices such as relays. It is pointed out that the limitations of the ENIAC are in its limited memory capacity, but its ability to perform 1,000,000 multiplications per hour is an extremely valuable feature. In conclusion, mention is made that general purpose calculating machines have a wide range of application; for example, to various problems in applied statistics, particularly in multiple correlation analysis, in which field there are many problems of economic, medical, and socialogical interest and importance awaiting study which at present is not undertaken because of the formidable load of computing involved. By D. R. Hartree. Cambridge, England, at the University Press; New York, N. Y., The MacMillan Company, 1947, 40 pages, paper bound, 5 by 7 inches, 75 cents.

"Varnished Cloths for Electrical Insulation." The authors collected information which was scattered throughout technical and trade literature, and added data from their own researches. Material is included on the textile support to which varnish is applied, how varnish contributes to the evolution of a flexible electrical insulator, and what processes the fabrics undergo to become the finished product. The book is divided into sections on the chemical and physical properties of textiles used in the manufacture of varnished cloth; oil base varnishes; the proofing of coating of cloth with varnish; the testing and use of varnish cloth; and then an appendix on standard specifications and test methods. By H. W. Chatfield and J. H. Wredden. Chemical Publishing Company, Inc., Brooklyn, N. Y., 1947, 233 pages, cloth-bound, $5^{1}/_{2}$ by $8^{3}/_{4}$ inches, $6.

The following new books are among those recently received at the Engineering Societies Library. Unless otherwise specified, books listed have been presented by the publishers. The Institute assumes no responsibility for statements made in the following summaries, information for which is taken from the prefaces of the books in question.

ADVANCED CALCULUS. By D. V. Widder. Prentice-Hall, New York, N. Y., 1947. 432 pages, diagrams, tables, $9^{1}/_{4}$ by 6 inches, cloth, $6.65. Designed for the student who is already familiar with the manipulations of elementary calculus, this text is so arranged that the separate chapters are more or less independent. This allows the selection of certain chapters, or the use of the early part of each chapter, at the discretion of the instructor or reader. Topics covered are: partial differentiation; vectors; differential geometry; applications of partial differentiation; the Stieltjes integral; multiple integrals; line and surface integrals; limits and indeterminate forms; infinite series; convergence of improper integrals; the gamma function; Fourier series; the Laplace transform, and its applications.

APPLIED MATHEMATICS FOR RADIO AND COMMUNICATION ENGINEERS. By C. E. Smith. McGraw-Hill Book Company, New York, N. Y., and London, England, 1945. 336 pages, diagrams, charts, tables, $8^{1}/_{2}$ by 5 inches, cloth, $3.50. Part of a series developed for home-study use, this book presents the fundamentals of arithmetic, algebra, geometry, trigonometry, curves and graphs, simultaneous and quadratic equations, differential and integral calculus, series, and wave forms. Assuming the equivalent of a high school education on the part of the student, the object of this book is to widen his range of understanding of the basic mathematical concepts for better comprehension of the technical literature in the field, and to lead toward research and design work.

COLLEGE PHYSICS. By J. A. Eldridge. Third edition. John Wiley and Sons, New York, N. Y.; Chapman and Hall, London, England, 1947. 720 pages, illustrations, diagrams, charts, tables, $8^{1}/_{2}$ by $5^{1}/_{2}$ inches, cloth, $4.50. This basic textbook is written and arranged in such a way as to be suitable not only for the student with a direct professional interest in the subject, but also for the nonscience major. Beginning with the physics of common knowledge, the text covers physics fundamentals in some 50 logically arranged chapters, from the study of matter in general to the emission and absorption of light. Review questions and practical problems accompany each chapter.

CONTRACTS IN ENGINEERING. By J. I. Tucker. Fourth edition. McGraw-Hill Book Company, New York, N. Y., and London, England, 1947. 341 pages, tables, $8^{1}/_{2}$ by $5^{1}/_{4}$ inches, cloth, $5. This textbook of legal principles for students, engineers, contractors, and businessmen covers the interpretation and writing of engineering–commercial agreements. The object of the book is to explain the fundamentals underlying a variety of cases and situations so that the guiding principles will be recognizable. A detailed index and several groups of study and review questions add to the practical value of the book for self-study.

ELECTRICITY; PRINCIPLES, PRACTICE, EXPERIMENTS. By C. S. Siskind. McGraw-Hill Book Company, New York, N. Y., and London, England, 1947. 448 pages, illustrations, diagrams, charts, tables, $8^1/_2$ by $5^1/_4$ inches, cloth, $2.60. The object of this book is to present the general elementary principles of d-c and a-c electricity, to show how these principles apply to the construction and operating characteristics of common types of circuits and machines, and to illustrate these principles by simple experiments with readily available apparatus. Electrical materials—copper, iron, insulations, and so forth—are discussed, with emphasis upon their uses and proportions in the construction of electric circuits and machines.

L'ÉLECTROCHIMIE ET L'ÉLECTROMÉTALLURGIE (two volumes). By A. Levasseur. Sixth edition revised, Dunod, Éditeur, Paris, France, 1947. Volume 1, 175 pages; volume 2, 202 pages, diagrams, charts, tables, $9^3/_4$ by $6^1/_2$ inches, paper. Volume 1 of this 2-volume set first discusses the various aspects of electrolytic theory. Succeeding chapters deal with the general principles of electrochemical and electrometallurgical applications, such as the alkali and chlorine industries, copper refining, electrodeposition of metals, and so forth. Volume 2 covers first the various types of electric heating equipment, including installation and control, and continues with descriptions of the important uses of electric furnaces in the fields of metallurgy, foundry practice, calcium carbide, and nitrogen production.

ENGINEERING ORGANIZATION AND METHODS. By J. E. Thompson. McGraw-Hill Book Company, New York, N. Y., and London, England, 1947. 337 pages, illustrations, diagrams, charts, tables, $9^1/_4$ by 6 inches, cloth, $4. This book furnishes industrial executives and supervisors with tested techniques for speeding up production and reducing costs in product-design engineering departments. Offering a specific fundamental plan for organizing, operating, and controlling these departments, it describes practical methods which have been used successfully in both large and small engineering sections of a wide variety of technical concerns. The book supplies the complete data necessary for the orderly preparation, processing, and recording of engineering information, and also includes a useful general discussion of the functions of supporting departments.

THE FUTURE OF TELEVISION. By O. E. Dunlap, Jr. (revised edition). Harper and Brothers, New York, N. Y., and London, England, 1947. 194 pages, illustrations, $8^1/_2$ by $5^1/_2$ inches, cloth, $3. This survey of the television industry describes briefly its progress to the present time; discusses the current major problems in financing, programming, scheduling, televising procedures, and so forth; and considers the consequences of future expansion on radio, the motion picture, the theater, the home, music, news, sports, business, and the commercial uses of a new medium. A chronology of the historic steps in television and a list of television stations are appended.

INVENTIONS AND THEIR MANAGEMENT. By A. K. Berle and L. S. de Camp. Second edition. International Textbook Company, Scranton, Pa., 1947. 742 pages, illustrations, diagrams, charts, tables, $8^1/_2$ by 5 inches, cloth, $6 ($5, college edition). This comprehensive work presents the principles and practices governing the technical, legal, and business procedures of invention, from the history and theory of the protection of ideas to the methods of exploitation. Numerous illustrative cases from actual experience are given. Foreign patents, trade-marks, and copyrights are discussed, and a glossary and a detailed index are included. The new edition contains a discussion of the Lanham Act and a new chapter on trends in industrial research and invention.

PAMPHLETS • • •

The Practical Training of Professional Electrical Engineers. This is a report recommending the further development of schemes of practical training for professional electrical engineers, published by the Institution of Electrical Engineers. The report has been prepared by a joint committee consisting of representatives of the British Electrical and Allied Manufacturers' Association, The Radio Industry Council, and The Institution of Electrical Engineers. Copies may be obtained, at 1s, post-paid, from the Secretary of the Institution of Electrical Engineers, Savoy Place, London, W. C. 2, England.

Departmental Co-operation in Cost Reduction (Financial Management Series Number 85). This is a collection of several papers that were presented at the Financial Management Conference of the American Management Association, December 6–7, 1945, New York, N. Y. Various phases of cost reduction and business are discussed with specific references to departments such as insurance, sales, customers' service, production, and office. The pamphlets are available from the American Management Association, 330 West 42d Street, New York 18, N. Y. 26 pages, price 50 cents.

The Foreman—The Job and The Man (Production Series Number 166). Three papers that were presented at the Spring Production Conference of the American Management Association, April 22–24, 1946, New York, N. Y. The topics include: The Foreman—The Job and The Man, Labor Relations Tools for Foremen, and Incentives Compensation for Foremen. The pamphlet is available from the American Management Association, 330 West 42d Street, New York 18, N. Y. 31 pages, price 50 cents.

Human Relations Opportunities for Management (Production Series Number 167). Three papers that were presented at the Spring Production Conference of the American Management Association, April 22–24, 1946, New York, N. Y. The topics include: Human Relations Opportunities for Management, A Production Improvement Program for Management, and The Future of Industrial Training. The pamphlet is available from the American Management Association, 330 West 42d Street, New York 18, N. Y. 34 pages, price 50 cents.

Cutting Tomorrow's Costs (Production Series Number 168). Four papers that were presented at the Production Conference of the American Management Association, November 14–15, 1946, Chicago, Ill. Topics include: Planning and Co-ordination, Product Research, Product Design, and Process Research. The discussion also is included. The pamphlet is available from the American Management Association, 330 West 42d Street, New York 18, N. Y. 55 pages, price $1.

Production Policies for Increased Output (Production Series Number 169). Four papers presented at the Production Conference of the American Management Association, November 14–15, 1946, Chicago, Ill. Topics include: Increasing Labor Productivity, The Economic Justification for Investment in Plant Assets, Incentive Plans Versus Measured Day Work, and Incentive and Work Standard Grievances. The pamphlet is available from the American Management Association, 330 West 42d Street, New York 18, N. Y. 36 pages, price 75 cents.

The Human Aspects of Methods Improvement (Production Series Number 170). Five papers that were presented at the Production Conference of the American Management Association, November 14–15, 1946, Chicago, Ill. Topics include: Workers Attitude Toward Cost Reduction and Methods Improvement, Getting Supervisors' Co-operation in Methods Improvement, Sound Compensation for Foremen, Freedom to Manage, and A Labor Leader Looks at Managements' Effort to Lift Output. The pamphlet is available from the American Management Association, 330 West 42d Street, New York 18, N. Y 50 pages, price $1.

Index to 1946 ASTM Standards. This index is an adjunct to the book of the American Society for Testing Materials Standards and comprises a ready reference for locating any ASTM Standards in the bound publication of the society in which it appears. The index is also of service in ascertaining whether the society has issued a standard on a specific subject. Copies of the publication are available on written request to American Society for Testing Materials, Headquarters, 1916 Race Street, Philadelphia 3, Pa. 242 pages, no charge.

Directory of Member Institutions and Review of Current Research, 1947. This publication is the new edition of a directory of member institutions of the Engineering College Research Council. This year (1947), following the merger of the Engineering College Research Association into the American Society for Engineering Education, the executive committee of the Engineering College Research Council authorized publication of the new edition in a revised form. It contains a list of the member institutions, their research director and officers, research personnel, expenditures, policies, and projects now active. A list of the active committees, officers, past officers, and bylaws of the Engineering College Research Council of the American Society for Engineering Education also is included. Copies are available from the Engineering College Research Council's office at the State University of Iowa, Iowa City, Iowa. 103 pages, price $1.

Basic Radio Propagation Predictions for October 1947, Three Months in Advance. CRPL-D35. A National Bureau of Standards publication which is available from the Superintendent of Documents, United States Government Printing Office, Washington 25, D. C. 28 pages, price 15 cents.